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THE ROENTGEN DIAGNOSIS OF RIGHT PARADUODENAL HERNIA*

REPORT OF A CASE WITH SURVEY OF THE LITERATURE

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ALTHOUGH herniae in the region of the duodenojejunal flexure have been known for over a century and a half they remain a subject of engrossing interest to those who are fortunate enough to encounter one. Moreover, after all this time and after intensive study by numerous observers, they continue to present many unsolved problems, etiological, anatomical, diagnostic, and therapeutic. This may be attributed in large measure to the rarity of the condition, and the resulting fact that most cases are seen by persons with little or no previous knowledge of the condition. The observer's interest is aroused, the subject is studied, and he is then in a position to profit by the chance to study another case, but rarely does a second opportunity arise. The literature must therefore consist almost entirely of single case reports which are of value only so far as they accurately and carefully describe the condition as found. Many excellent descriptions have been published but unfortunately they are in the minority and, as the relationships which occur are so complex that the best of descriptions never tell the whole story, it is only with great difficulty that one can piece together a reasonably complete picture of paraduodenal hernia in its various aspects. It seems, therefore, that there is still a definite place for individual reports of any cases which have been sufficiently observed to contribute any reliable information.

Knowledge of this condition in its roentgenological aspects is still very limited although it is now over ten years since Kummer[26] first visualized a left paraduodenal hernia. Since that time Case and Upson,[6] and Taylor,[40] have described cases diagnosed by roentgen examination. That of Case and Upson was probably one of right paraduodenal hernia, judging by the roentgenograms, but apparently they did not differentiate between the right and left sided varieties in their diagnosis, and they give no description by which one may decide which type they had. So probably Taylor's claim to have been the first to diagnose a right-sided paraduodenal hernia preoperatively should be accepted. In that event the present case would be the second on record.

From this it must be apparent that the subject is in its infancy, and that any conclusions drawn from such limited material must be subject to alteration and re-

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vision in the light of further observations as they become available. I would not even consider reporting on such fragmentary evidence were it not that there is slight prospect of securing a larger series of cases.

It seems, too, that there is need for much wider dissemination of what knowledge we do possess regarding the roentgen diagnosis of this condition. Very few of the recent cases have had roentgen examinations, and with but one or two exceptions the authors seem unaware that anything has been done along that line. For example Masson and McIndoe[30] in 1930 state that right paraduodenal hernia "never has been diagnosed before operation or necropsy" and that "roentgenographic studies have not aided in the diagnosis." A similar statement is made by Deaver and Burden[11] in 1929, and again by Dowdle[14] in 1932, while Brohée[4] in 1931 credits Kummer alone with the observation of roentgen findings.

According to Moynihan,[32] there are four regions in the posterior abdominal wall where herniae are prone to occur: (1) into the lesser peritoneal sac, (2) into the intersigmoid fossa, (3) into one of the fossae about the cecum and (4) into one of the fossae around the duodenojejunal flexure, of which he describes nine. Certain herniae have been described which do not conform to his classification, but (so far as I know) we have no better classification available at the present time.

With possible very rare exceptions all of the herniae in the region of the duodenum may be classified as of two general types. Each of these has been known by various names, given by different observers, but we shall refer to them as right and left paraduodenal hernia respectively. In the typical forms the hernial sacs correspond in their relationships to enlargements of two of Moynihan's nine fossae, the right paraduodenal hernia corresponding to the mesenterico-parietal fossa (fossa of Waldeyer), and the left paraduodenal hernia corresponding to the paraduodenal fossa (fossa of Landzert).

OCCURRENCE

Both types are distinctly uncommon, the right-sided lesion being much the rarer of the two. Forlini[18] reports but 5 paraduodenal herniae in a total of 25,500 autopsies, or one in 5,100 cases. In all there are said to be not over 150 cases of left paraduodenal hernia reported.

Nagel[33] in 1923 collected from the literature 28 cases of right paraduodenal hernia and added one of his own to make a total of 29. In addition he reported 4 cases supposed to be of this type but which he did not accept as authentic because they were inadequately described. Short[39] in 1925 collected a few additional cases but at least one of these cannot be accepted as authentic.

I have been able to find in the literature since 1923, ten additional cases as well as 3 which are not sufficiently described to be called authentic. One, that of Novak and Sussman,[34] which was published as right paraduodenal hernia and was accepted as such by Short[39] and by Brown,[5] must, from its description, be classed as left paraduodenal hernia, and so is not included. A few retroperitoneal herniae have been reported in periodicals which are not available, so it is possible that among these there may be still another case or two of this type. To these must be added the present case, bringing the total of authentic cases to 40.

It is noteworthy that among the 32 cases where the sex is given there are only 5 females, of which the present case is one. This gives us the rather surprising sex ratio of 5 males to 1 female.

The ages varied from three months to sixty-eight years as follows:

0–9	10–19	20–29	30–39	40–49
3	3	6	3	6
50–59	60–69	Not given		
5	2	12		

FACTORS IN MORTALITY

Nagel,[33] in 1923, could find no single case where diagnosis of right paraduodenal

hernia had been made prior to operation or autopsy, although the left-sided variety has been so diagnosed on several occasions. Of the authentic cases diagnosed prior to 1923, fifteen gave symptoms of acute intestinal obstruction, while in 13 cases no information is given on this point. In 12 cases operations were performed and only 2 recovered. In the 4 unauthentic cases there was also one cure.

In sharp contrast are the cases since 1923, for although 6 of the 10 gave symptoms of acute obstruction, and all 10 were operated upon, there were only 2 deaths.

We can divide the history of this condition, then, into three distinct periods:

1861–1903, when 19 cases were described but only 4 operations were performed and only one patient recovered.

1904–1923, when 10 cases were reported with 8 operations, but still with only one recovery.

1923–1932, when 10 cases were reported and all were operated upon, with 8 recoveries.

FIG. 1. Left paraduodenal hernia as seen at autopsy. The sac contains the entire small bowel, except the terminal 5 inches. (From Desjardins.[12] Reproduced by permission of *Annals of Surgery*.)

TABLE I

RIGHT PARADUODENAL HERNIAE REPORTED SINCE 1923

Observer	Year	Age	Sex	How Diagnosed	Acute Obstruction	Operation	Result	Roentgen Examination
Lower and Higgins	1925	13	F	Operation	No	Yes	Cure	None
Brown	1925	49	M	Operation	No	Yes	Cure	Reported negative
Bernardbeig	1925	56	M	Operation	Yes	Yes	Death	None
Deaver and Burden	1929	25	M	Operation	Yes	Yes	Cure	None
Flechtenmacher	1929	38	M	Operation	Yes	Yes	Cure	None
Taylor	1930	32	M	Operation	No	Yes	Cure	Typical
Taylor	1930	24	M	X-ray	No	Yes	Cure	Typical
Masson and McIndoe	1930	41	M	Operation	Yes	Yes	Cure	Reported negative
Cofer and Phillips	1930	22	M	Operation	Yes	Yes	Death	None
Dowdle	1932	24	M	Operation	Yes	Yes	Cure	None
Case and Upson*	1926	—	—	X-ray	—	Yes	—	Typical
Eitel†	1926	22	M	Operation	No	Yes	Cure	None
Venables**	1930	58	M	Operation	No	Yes	Cure	Stasis in jejunum

* The authors do not distinguish definitely between right and left paraduodenal hernia, but it was probably the former.

† Inadequate description but probably right paraduodenal hernia.

** On the right side "behind the duodenum." Relations of the orifice not described.

This abrupt change in the mortality rate cannot be explained by better diagnosis for, as we have seen, only 2 of the 10 were correctly diagnosed preoperatively. Other

FIG. 2. Right paraduodenal hernia as seen at autopsy. The sac (*b*) is greatly shrunken, having been emptied of the herniated bowel at operation a few days before death. The orifice is clearly shown behind the root of the mesentery just to the right of (*a*). (From MacCallum and Miller.[29] Reproduced by permission from the *Johns Hopkins Hospital Bulletin*.)

explanations which we must consider are: improved operative technique in intestinal surgery; improvement in the early recognition and operative treatment of intestinal obstruction in general; increased interest in the subject following the publication of Nagel's paper, resulting in the recognition and reporting of cases which would otherwise have been missed.

ANATOMICAL CONSIDERATIONS

It is characteristic of both left and right paraduodenal herniae that they are almost always either total or subtotal, or, in other words, that all or nearly all of the small bowel is included within the hernial sac (see Fig. 1). It necessarily follows that the resulting mass will fill a large part of the abdominal cavity, and that such large herniae will have very similar appearance and relations even when of totally different origin. The only way of positively identifying such herniae must be by means of the relations of the hernial orifice, and particularly by its vascular relationships.

For example, in the left paraduodenal hernia, reported by Desjardins[12] in *Annals of Surgery*, 1918, and illustrated in Figure 1, the colon surrounds the hernial sac, which has its orifice in the lower right side just opposite the cecum, but the colon can just as easily run across the front of the sac or be buried behind it or lie almost entirely to the right of it in an almost endless variety of arrangements. The sac itself may lie high or low, well to the left or in the midline, and may even have its lower pole well down in the pelvis. But one will always find in or near the anterior free margin of the orifice the "vascular arch of Treitz" consisting of the inferior mesenteric vein and the left colic artery.

One peculiar thing about this type of hernia is that, contrary to what one might expect, almost invariably only the efferent loop of bowel passes through the hernial orifice. The afferent loop enters the sac from behind, where the duodenum emerges from its retroperitoneal position, at the duodenojejunal juncture; or, as in one case, it may emerge just beside the sac and enter the sac obliquely from the side. This peculiar arrangement is too constant to be accidental, and it seems to me that it has not received the attention it deserves in the consideration of the genesis of this hernia.

Figure 2 represents a case of right paraduodenal hernia, which was reported by MacCallum and Miller[29] in the *Bulletin of the Johns Hopkins Hospital*, 1908. The picture was made at autopsy a few days after an operation at which the hernia was emptied. The sac is consequently greatly shrunken, but the orifice and the general relations are well shown. The sac in this

case lies behind the transverse and ascending mesocolon, but, as in the left-sided variety, the colon may have almost any relationship to the sac. It differs, however, in that *both the afferent and the efferent loops of bowel always pass through the hernial orifice*. Moynihan[32] gives the following points as characteristic of this type of hernia:

1. The hernial sac occupies—at any rate, at first—the right half of the abdominal cavity, lying behind the ascending and the transverse mesocolon.

2. The orifice is situated behind and to the left of the sac, on the lumbar vertebrae.

3. In the anterior margin of the sac there lies either the superior mesenteric artery, or a continuation of it, the ileocolic artery.

Before the withdrawal from the sac of the intestinal loops with their mesentery, the mesentery was folded back upon itself at the line of the superior mesenteric

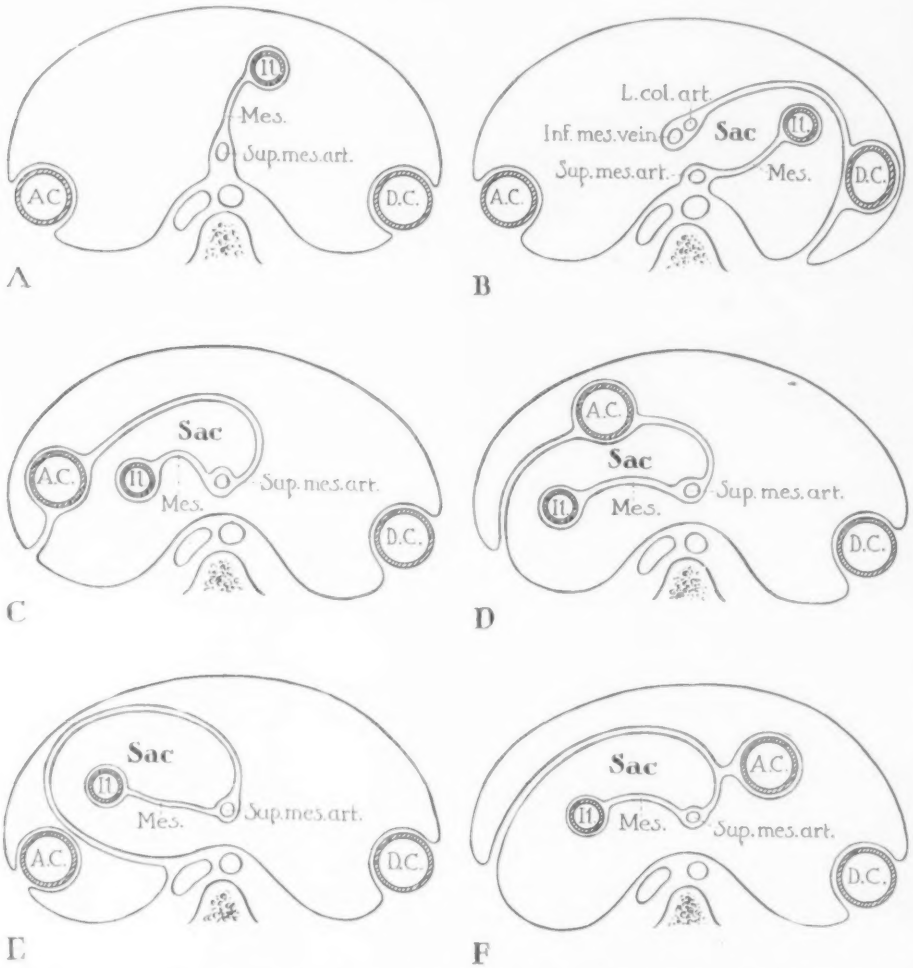

Fig. 3. Peritoneal relations in cross section, at level of hernial orifice, viewed from below. *A*. Normal peritoneal relations. *B*. Left paraduodenal hernia with descending colon lateral to the sac (usual arrangement). *C*. Right paraduodenal hernia with ascending colon lateral to sac. (This and *D* are the usual types.) *D*. Right paraduodenal hernia with ascending colon anterior to sac. (Author's case was of this type.) *E*. Right paraduodenal hernia with ascending colon hidden behind the sac. (Brown's and MacCallum and Miller's cases.) *F*. Probable arrangement in Nagel's case. The unusual position of the ascending colon would cause it to simulate the roentgenologic appearance of complete intestinal non-rotation. *A.C.* Ascending colon; *D.C.* Descending colon; *Il.* Ileo-jejunum.

artery, so as to lie wholly within the sac and appeared to spring from the inner margin of the hernial orifice. This relationship will perhaps be best understood by referring to Figure 3.

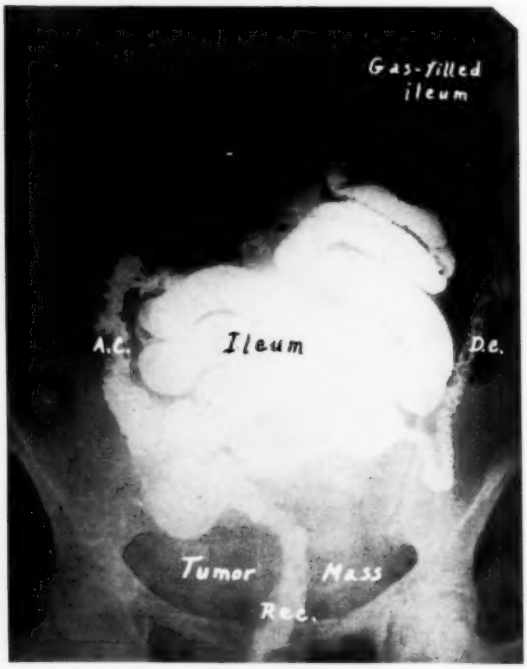

FIG. 4. Right paraduodenal hernia. Roentgenogram following evacuation of barium enema. The terminal ileum has been filled through the ileocecal valve. It is dilated to the size of a normal colon and is continuous with the dilated and gas-filled loops under the left diaphragm. The collapsed colon (*A.C.* and *D.C.*) is also shown. The pelvis is occupied by tumor mass.

CASE REPORT

The following case, which was successfully diagnosed by roentgen examination, was of this type. The relationships found at operation were those diagrammatically represented in the cross section in *D* of Figure 3.

L. P., married, white, female, housewife, aged fifty-six, was admitted to the University Hospitals on April 30, 1931. She was sent in from the Out-Patient Department with a diagnosis of ascites, cause undetermined, and left inguinal hernia. Her complaints dated from seven weeks before admission when there was a sudden enlargement of the left inguinal hernia associated with pain radiating over the entire abdomen. The hernia was reduced but the pain continued at intervals. Beginning three weeks later, she noticed a gradual, progressive enlargement of her abdomen, followed by a decrease in the abdominal pain and tenderness. She still had some pain on change of position, e.g. arising from a supine position.

Her past history contained but little of interest, other than certain rather indefinite gastrointestinal complaints. At times during the past two years she had had attacks of pain in the right upper abdominal quadrant, occasionally radiating to the scapula, and apparently aggravated by fats. She complained also of intermittent bloating and a tendency to constipation.

An incarceration of the inguinal hernia, which had occurred four years before, had been reduced without operation.

Physical examination on admission was practically negative, except for the abdomen, which was markedly distended and showed evidence of marked ascites. A definite generalized abdominal tenderness was noted. A small left inguinal hernia was found.

Paracentesis on May 2, 1931, resulted in the removal of 300 c.c. of clear fluid.

Pelvic examination on May 6 revealed two large, rounded masses in the pelvis and a diagnosis of "carcinoma of the ovary with extension" was made.

Barium enema examination was done on May 11. On this examination several gas-filled loops of small bowel were observed lying just under the left diaphragm, so an attempt was made to determine the cause of this by study of the passage of a barium meal through the intestinal tract.

The roentgen report was in brief as follows:

The colon showed no intrinsic pathology, but revealed pressure on both sides of the rectum, especially on the right. There was slight upward displacement of the sigmoid. The barium passed readily through the ileocecal valve, filling the terminal ileum, which was displaced upward out of the pelvis. Some loops of the mid-ileum are seen distended with gas and lying almost under the left diaphragm (see Fig. 4).

The terminal ileum is greatly dilated. Both the splenic and hepatic flexures are low, and the ascending colon is displaced slightly toward the midline.

Roentgenograms taken with the patient standing, two hours and five hours after the barium meal, show the upper half of the stomach greatly ptosed into the left lower quadrant. The antrum and pyloric portion appear to be held up by a mass about 5 cm. in diameter overlying the first and second lumbar vertebrae (see Fig. 5). The mass over which the stomach is lying appears to consist of a number of dilated loops of small bowel.

Roentgenograms taken at five hours show a very definitely and sharply circumscribed mass, about 20 cm. in diameter, lying in the right half of the abdomen, at the level of the first to the fifth lumbar vertebrae. This consists of barium-filled loops of small bowel which give the impression of being confined, as within a hernial sac (see Fig. 6). This appearance is said to be characteristic of paraduodenal hernia, which diagnosis is entirely consistent with all the other findings.

Roentgenograms taken nine hours after the barium meal show this area of bowel almost completely emptied. There are, however, one or two loops of barium-filled bowel still present in this region. There is now shown (see Fig. 7), at about the position of the duodenojejunal junction, a loop of ileum which shows an abrupt transition from a comparatively narrow caliber in the portion occupying the right side of the abdomen, to a much larger caliber in the part extending upward and to the left. This apparently marks the point of exit of the efferent loop of ileum from the sac. This larger ascending limb connects with the gas-filled loops of ileum previously visualized in the region of the left diaphragm.

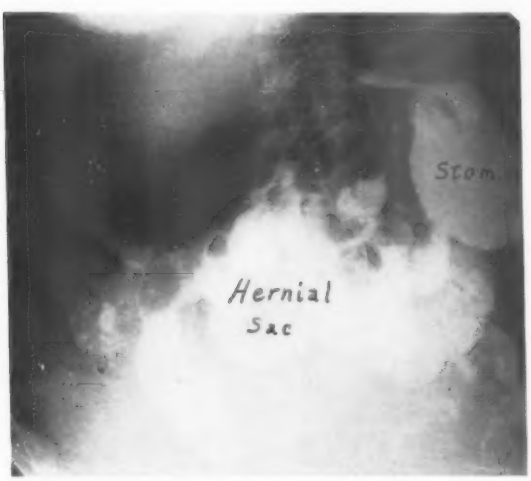

Fig. 5. Right paraduodenal hernia. Roentgenogram made in the erect position five hours after the ingestion of barium. The corpus of the stomach has sagged down to the left of the hernial sac, while the antrum is held up by a mass of gas-filled loops of bowel.

Fig. 6. Right paraduodenal hernia. Roentgenogram made in the prone position five hours after the ingestion of barium. The rounded, sharply circumscribed mass of barium and gas-filled loops of small bowel are clearly shown.

At twenty-one hours, almost the entire meal is in the descending colon and rectum.

Conclusions: (1) Mass in the pelvis with pressure on rectum and displacement of colon and ileum. (2) Probable right paraduodenal hernia.

Laparotomy was performed by Dr. Kasper on May 21, 1931, under spinocain anesthesia. A large right paraduodenal hernia was found. It was easily emptied of its contents by traction on the bowel, but no attempt at repair of the sac was made because of the pelvic condition. An attempt was made to remove all the carcinomatous material from the pelvis, and the few nodules in the omentum were also removed. The patient went into shock and was transfused.

She made an uneventful postoperative recovery, following which she was given deep roentgen therapy. There has been some recur-

rence of the carcinoma but she is otherwise in good condition.

Roentgen examination on May 22, 1932, shows perfectly normal gastrointestinal relationships except for a moderate degree of ptosis. There has been no recurrence of the herniation

PREVIOUS LITERATURE ON ROENTGEN FINDINGS

Before discussing in detail the differential diagnosis it might be well to review the previous literature regarding the roentgen findings in this condition and in the very similar left paraduodenal hernia.

Wagner,[44] *1916*. Wagner described marked duodenal stasis occurring in a fourteen year old girl as a result of left paraduodenal hernia, and discussed in detail the various causes of duodenal stasis. He found a large gas bubble in the duodenum above a broad fluid level. The opaque meal sedimented out below this fluid level and in the first loop of the jejunum. At the end of six hours none of the meal had passed beyond this point.

The stomach was not dilated, showed hyperperistalsis, and was situated rather high in the abdomen.

Operation revealed a large left paraduodenal hernia, but no detailed description of it is given. The duodenum was dilated to the size of a man's arm.

Repeated examinations after recovery showed a return to normal in the caliber of the bowel, and a progressive ptosis of the stomach, suggesting that the previous high position of the stomach was associated with the presence of the hernia.

Hayes,[21] *1920*. I have been unable to obtain the original article but it has been abstracted as follows by Philips:[36]

Male, aged sixty-eight, complained of colicky pain for one year. Roentgen examination of the gastrointestinal tract showed dilated stomach and duodenum with elongation of the latter. Barium meal passed through the beginning jejunum only after six hours and then moved onward very slowly, arriving at the transverse colon after fifty-four hours. Operation: Jejunum was found engaged in left paraduodenal hernia and was withdrawn. The patient recovered.

Scheele,[38] *1921*. Scheele quotes Wagner's case and describes very similar findings in his case, in the region of the duodenum and stomach. Enough barium went through, however, to visualize the small intestine. This was situated unusually high and was bounded below by a curved line, convex downward. In the lower abdomen and pelvis there were no small bowel shadows. This curved lower boundary he interprets (probably correctly) as the lower pole of the hernial sac, and considers that, if the plates had been more critically examined, it should have been possible to make a preoperative diagnosis.

At operation, a large subtotal left paraduodenal hernia was found and reduced. Examination after operation showed the normal arrangement of the small bowel loops, with shadows lying deep in the true pelvis.

Kummer,[26] *1921*. Kummer also described a left-sided hernia, the second in which the hernia itself was visualized. He notes the following points in the examination: (1) A total absence of small bowel in the true pelvis in the upright position; (2) the confining of the small intestine in a smooth, sharply circumscribed mass; (3) in the right lateral decubitus position (i.e., with the patient lying on the right side, and the rays passing through from behind), the small intestine, enclosed in the retroperitoneal sac, casts on the plate an oval shadow of which the main axis lies a little to the left of the midline of the body, and of which the right border is separated from the shadow of the stomach by a clear space. In the normal, on the other hand, in this position the small bowel tends to slide into the right flank, and its shadow touches and overlaps to some extent that of the stomach.

Nagel,[33] *1923*. Regarding the roentgen findings in his case, he says, " . . . The condition appeared to represent an *incomplete intestinal rotation* and no further significance was attached to it." Since Case and Upson have stated that his published plates and those of Lower and Higgins show the characteristic picture of paraduodenal hernia, we must determine if possible whether this is likely to be a difficult differentiation to make.

Examination of the illustrations of Nagel's case has convinced us, on the contrary, that this case is unique in the arrangement of the ascending colon which caused it to resemble a non-rotation (see Fig. 3). I have been unable to find among the cases of hernia which have been adequately described a single case show-

ing this arrangement. Lower and Higgins have, to be sure, published a case in which the illustrations show the same arrangement, but there is no adequate description of the course of the colon, and the exact findings are not clear.

Levin and Ellis,[27a] *1924*. Levin and Ellis reported marked gastric retention (slight retention after seventy-two hours) in a case of retroperitoneal hernia which is poorly described and was doubtless atypical. The superior mesenteric artery was not in the margin of the orifice, and only 15 to 18 inches of jejunum was herniated.

Lower and Higgins,[28] *1925*. Their article contained, in addition to the right paraduodenal hernia mentioned above, an account of a left-sided hernia in which two roentgenograms are shown. These, too, were said by Case and Upson to show the characteristic appearance of paraduodenal hernia. The first, however, shows only a rounded area of pressure on the medial aspect of the cecum, the characteristic appearance of any extracecal mass. There is also some barium in the terminal loops of ileum, but it, too, shows only the evidence of pressure from a large external mass, there being nothing to indicate the nature of the mass. The second shows some loops of small bowel which are probably within the sac, but it does not seem to me that the appearance is sufficiently definite to be considered characteristic. It does, however, suggest that a more complete filling would probably have produced the typical picture.

At operation for suspected tumor of the cecum, a large left-sided hernia was found but could not be reduced on account of adhesions. Again we are handicapped by the inadequacy of the description, and by the fact that the illustration of the hernia is obviously incorrect, as the course of the colon in the illustration is not at all that shown in the roentgenogram, and the relations shown are impossible in a left paraduodenal hernia.

Case and Upson,[6] *1926*. Their article is of particular interest because it contains what is, from its appearance, the first published roentgenogram of a right paraduodenal hernia. In addition, it is an unusually clear illustration of the typical findings. They make the statement that a correct diagnosis was made preoperatively, but, aside from the paragraph heading of "paraduodenal hernia," there is no statement or description by which one can determine which type of hernia was diagnosed or found. In addition they give as illustrative of the findings, a picture, taken from Moynihan,[32] of Neubauer's case of *left* paraduodenal hernia, and they state that they do not believe it possible to differentiate between the right and left herniae by roentgen examination. In view of these facts I do not believe that they can rightly claim priority over Taylor in the preoperative diagnosis of right paraduodenal hernia.

A second case of retroperitoneal hernia is also reported as correctly diagnosed preoperatively. As in the other case, no other information is given, and certainly the published roentgenogram contains nothing characteristic of hernia. It merely shows the terminal ileum, as outlined by retrograde filling from the colon, coursing upward to a point behind and above the transverse colon, instead of into the pelvis as is usually the case.

Christophe and Hartmann,[7] *1926*. They described findings similar to Wagner's, in a case which they call left paraduodenal hernia. The hernia which was apparently rather small, is poorly described, although two operations and an autopsy were performed.

Taylor,[40] *1930*. To Taylor should be given credit for the first preoperative diagnosis of right paraduodenal hernia. He reports two cases, only the second having been diagnosed preoperatively. Both had, in addition, a duodenal ulcer. Both were verified at operation.

He describes both as having a "bunched appearance of the small gut, as if it were contained in a bag." A single illustration of each case verified this statement.

Venables,[43] *1930*. He described a case which may have been of the same type, but, from the rather inadequate description, it seems doubtful. Roentgen examination showed marked stasis of the barium in greatly dilated loops of jejunum in the left upper quadrant. After $6\frac{3}{4}$ hours, however, these loops were practically empty and the barium was in the colon. They diagnosed a partial obstruction and considered the possibility of an internal hernia. Upon operation "a retroperitoneal hernia was felt, and by manipulation a coil of small intestine was delivered from a right retroperitoneal hernial sac behind the duodenum. The jejunum above the entering loop was enormously hypertrophied and dilated."

Behr,[2] *1931*. Behr made a diagnosis of probable left paraduodenal hernia on the basis of the combined physical and roentgen findings of duodenal stasis, plus a history of intermittent attacks of non-fecal vomiting over a period of

years. The diagnosis has never been verified by operation.

Of the above observers, only Venables has published no roentgenograms. A few others have reported negative roentgen examinations.

TECHNIQUE OF EXAMINATION

The examination should be largely roentgenoscopic, with enough plates to record and verify the findings. It should include a barium meal followed at frequent intervals as it passes through the intestine. The patient should be examined in the erect, prone and supine positions, and possibly in the right and left lateral decubitus positions. Lateral and oblique plates are often of value. The use of water as the medium for the suspension of the barium hastens the emptying of the stomach, and facilitates the examination. Repeated small meals of barium may help by outlining a larger part of the bowel at one time. The direct introduction of the barium meal into the duodenum through a Rehfuss tube may aid at times.

It is sometimes possible to outline the colon at the same time as the small bowel, by inflating the colon with air. This avoids confusion from the superimposition of colon and small bowel shadows.

The course of the colon should be determined by barium enema or by following the barium meal at twelve and at twenty-four hours. The course of the terminal ileum and the ileocecal relations should be carefully determined.

Naturally such a time-consuming examination will only be undertaken when one has reason to suspect some abnormality, but I believe that, if the possibility of this diagnosis is kept in mind, the diagnosis will be made with increasing frequency.

SUMMARY OF THE ROENTGEN FINDINGS IN RIGHT PARADUODENAL HERNIA

1. The most characteristic sign is a clumped appearance of the intestinal coils, as if they were contained in a bag (Fig. 6).

2. The coils cannot be displaced from this circumscribed mass by any amount of manipulation or change in position of the patient.

3. The axis of this ovoid mass of bowel loops is usually somewhat to the right of the midline of the body.

4. In the erect position, the corpus of the stomach tends to sag down to the left of the sac, while the antrum and pylorus are held up in position (Fig. 5).

5. There tends to be an absence of small bowel loops in the pelvis. This is not necessarily true, however, for a part of the terminal ileum is always outside the sac, and some of its loops may be in the pelvis. Moreover, in certain cases of left paraduodenal hernia,[23] the lower pole of the sac is within the pelvis, and it is possible that similar right-sided cases may exist.

6. The herniated bowel has shown, in all cases thus far reported, some loss of motility; so that there is more or less delay in the passage of barium through the sac. This stasis helps to visualize an unusually large part of the bowel at one time, and so accentuates the characteristic appearance. It seems probable that, due to this stasis, a flat plate of the abdomen, made without barium, would show more or less gas in the herniated bowel. This has never been verified.

7. It is possible at times to visualize the point of exit from the sac by an abrupt change in the caliber of the bowel as it emerges (Fig. 7).

DIFFERENTIAL DIAGNOSIS

It is well known that the successive loops of the small bowel tend to be arranged in clusters corresponding to the six primitive loops of the embryonic small intestine. The resulting clumped appearance of the bowel loops may stimulate that found in hernia. The outlines of the bowel cluster are less regular, however, and the loops can be displaced by manipulation.

The absence of small bowel in the pelvis is not essential, as we have seen, and if present may be due to a pelvic tumor, a

full bladder or rectum, a low, distended sigmoid colon, an enlarged uterus, or even an unusual amount of fat.[10] In most such conditions, however, the lower border of the bowel-containing area is convex upward instead of downward as in hernia.

Differentiation from left paraduodenal hernia should usually be possible. In left-sided herniae the ovoid mass of bowel tends to lie more to the left side, and in right-sided herniae more to the right side of the midline of the body. In left-sided herniae the stomach tends to ride high on top of the sac, while in right-sided hernia it tends to sag downward to the left of the sac. The clear space between the stomach and the sac, which was described by Kummer[26] as characteristic of left paraduodenal hernia, was also present in Case and Upson's[6] and in my case. That it is not necessarily present in right paraduodenal hernia is proved by the overlapping of stomach and sac shown in one of Taylor's[40] cases. Possibly further experience will show that it is not necessarily present in the left-sided variety either.

Fig. 7. Right paraduodenal hernia. Roentgenogram made in the prone position nine hours after the ingestion of barium. At the arrow is a loop of ileum which shows an abrupt change in caliber as it emerges from the hernial sac. The loops outside the sac are shown to be continuous with the dilated, gas-filled loops under the left diaphragm.

Fig. 8. Complete intestinal non-rotation. An ovoid and circumscribed mass of small bowel loops is shown. This closely simulates the appearance of a hernial sac. The afferent loop enters, however, at *A* where the duodenum courses directly to the right instead of curving to the left in the usual manner. (Compare with Fig. 9.)

In left-sided herniae the ascending colon lies always to the right of the sac, while the descending colon may run in front, to the left, or behind. The only exceptions that I know of are two cases where a part of the ascending colon was within the sac. In right-sided herniae the descending colon is always to the left of the sac. The ascending colon may be either to the right of the sac, behind it, or in front of it. In one case (Nagel's) it even lay in front and slightly to the left.

Case and Upson[6] have stated that differentiation from intestinal non-rotation is very difficult, but there really should be no reason for confusion except in that rarest

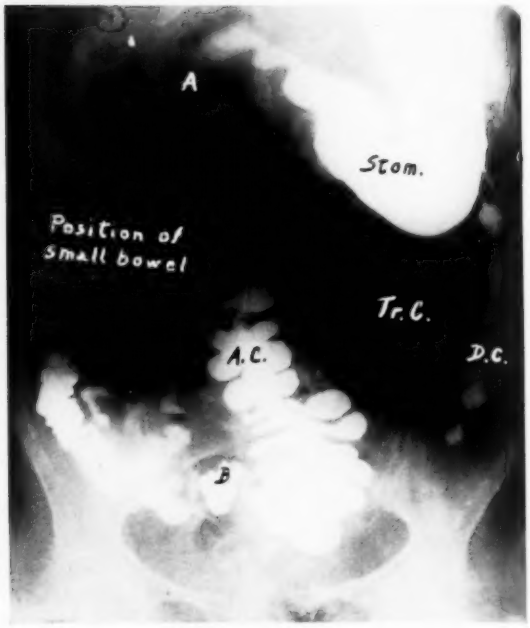

FIG. 9. Complete intestinal non-rotation. (Same case as Fig. 8, later and after the ingestion of more barium.) The afferent loop of small bowel is shown at *A*, as in Figure 8. The efferent loop, at *B*, consists of terminal ileum. Obviously the two loops do not pass through a common orifice. The position of the ileocecal valve at the right of the cecum is typical of non-rotation.

type of right-sided hernia of which Nagel's is probably the only example. If we bear in mind that in non-rotation of the intestine the cecum is reversed, with the ileum entering it from the right, it should be readily possible to differentiate between the usual types of hernia and non-rotation by visualizing the ileocecal junction. In Nagel's films, as illustrated, it is impossible to see the ileocecal relationship, but it is probable that the terminal ileum entered from the back and slightly from the right. Even if such is the case, there is one difference which should aid us.

In the right-sided hernia, which is the only one we need consider, the afferent and efferent loops of bowel both pass through the orifice,* and so must lie at least fairly close to each other. Contrast with this the condition shown in Figures 8 and 9, which I believe to be a simple non-rotation, although the picture closely simulates that of right paraduodenal hernia. Here the afferent loop enters the circumscribed area of small bowel loops at its upper pole, where the duodenum is seen to run directly to the right without the usual duodenojejunal flexure, while the efferent loop leaves this area at the lower pole, where the terminal ileum enters the cecum from the right. It is true that the orifice may be rather large, as in the case of Gerard-Marchant,[32] but it does not seem possible that it could be of such size as to permit this arrangement.

The position and course of the terminal ileum become, therefore, of prime importance in the differentiation of these conditions, and this is often best visualized by retrograde filling, through the ileocecal valve, by means of the barium enema. Fortunately the valve is sufficiently patent to permit this in about 90 per cent of the cases.

There remains to be considered the differentiation from certain rare abdominal anomalies. Of most of these only a single case has been reported, and, as there have been no descriptions of the roentgen findings, we can only surmise what they would show. We shall mention only a few which reveal points of particular interest.

Chief among these are the subtotal "pericecal" herniae described by Copenhaver[9] and by Fleming.[17] The usual types of pericecal herniae are relatively small and should offer no differential problem, but these cases have nothing in common with the ordinary types except the name. We cannot present here the evidence, pro and con, for the contention that all right-sided herniae, lying behind the mesentery or mesocolon, result from mal-rotation of the intestine. This results in the imprisoning of a part of the small bowel behind the mesentery and mesocolon, when they adhere to the posterior parietal peritoneum. We can merely state that the majority of

* I believe the only exceptions to this statement are the cases described by Telfer[41] and by Fleming.[17] These have never been classified as right paraduodenal hernia, but they undoubtedly represent the same type of anomaly, and can only be excluded by technicalities of definition which are of doubtful validity.

these herniae are most readily explainable on this assumption. (A similar explanation of the left-sided variety is less convincing.) If this explanation is correct, these two "pericecal" herniae are really only variants of our "right paraduodenal hernia."

Fleming's[17] case is of interest because, if we accept it as such a variant, it is an exception to the rule that, in right paraduodenal herniae, both the afferent and the efferent loops of bowel pass through the orifice. Telfer's[41] case which is another variant is also an exception to this rule, but here the sac contained only a few loops of jejunum.

Copenhaver's[9] case of "pericecal" hernia is of interest because it closely simulates the paraduodenal hernia described by Nagel. It differs only in the somewhat lower position of the orifice, and would be very difficult to distinguish, by roentgen examination, from a simple non-rotation. In fact, that diagnosis was actually made. Unfortunately the description is incomplete and the position of the afferent loop cannot be determined. We might state here that the relations shown by Nagel's and Copenhaver's cases are, of all right-sided hernias, the ones most difficult to explain on the basis of intestinal mal-rotation.

Of considerable interest is the case of Le Jeune and Guilloux[27] in which, in a completely non-rotated bowel, a portion of the small intestine was herniated from right to left into a sac behind the ascending colon and its mesocolon.

The case described by Hepworth[22] would give roentgen findings similar in all respects to those of left paraduodenal hernia. It is quite probable they should be classified together anatomically as well, in spite of the differences in vascular relations. The same can be said for the case described by Primrose.[37]

The case reported by Nuzum and Nuzum,[35] and erroneously classified as intersigmoid hernia, is obviously, from the relations of its orifice, more closely allied with the left paraduodenal hernias, differing from them, however, in the vascular relations, and in that both the afferent and efferent loops pass through the orifice. Its roentgen findings would never be confused with those of right paraduodenal hernia.

Another condition which might possibly simulate some of the findings of right paraduodenal hernia, is that presented by the cases described by Twyman[42] and by Jalcowitz.[25] In these the small bowel passed through a tunnel behind the ascending mesocolon and emerged at the right of the ascending colon. No actual sac was present in these cases.

The possibility of such anomalies must always be considered when making a roentgen diagnosis of right paraduodenal hernia, and only by the most thorough examination coupled with a careful analysis of all the findings can we hope to avoid errors. It should be remembered, however, that (except for complete non-rotation) such anomalies are very rare, even in comparison with right paraduodenal herniae, and that the percentage will favor the latter diagnosis in cases of genuine doubt.

SUMMARY

The occurrence, anatomy, and history of right paraduodenal hernia are briefly reviewed. Ten recent cases are collected from the literature. These with the author's case and the 29 collected by Nagel in 1923, make a total of 40 authentic cases. The roentgen findings are described in a verified case, the second which has been diagnosed preoperatively. The previous literature on the roentgen findings in both right and left paraduodenal hernia is critically reviewed. The roentgen findings and the differential diagnosis of right paraduodenal hernia are discussed in detail.

CONCLUSIONS

The roentgen diagnosis of both left and right paraduodenal hernia is possible in most cases.

Differentiation between the two types can usually be made with a fair degree of accuracy.

Differentiation from intestinal non-rota-

tion should cause difficulty only in very exceptional cases, and even in such cases should be possible.

Only by thorough and painstaking examination of the entire intestinal tract, and by careful analysis and evaluation of the relationships revealed, can we hope to make the diagnosis consistently.

The examination should include both the barium meal and the barium enema. The enema should be forced through the ileocecal valve if possible. The barium meal should be observed at frequent intervals and in a variety of positions as it passes through the intestinal tract.

ADDITIONAL NOTE: Since this paper was written we have had a case of left paraduodenal hernia which was also diagnosed preoperatively by roentgen examination, and which corresponded in its findings with the conclusions we have previously drawn and which are set forth in this paper. It is probable that this case will later be reported in detail.

The patient whose condition is reported in this paper died at her home in February, 1933, from recurrence of carcinoma. Unfortunately, we were not notified of her death until several weeks later, so no autopsy was obtained.

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PHYSIOLOGIC VARIATIONS IN THE CONTOUR OF THE DIAPHRAGM SIMULATING ORGANIC DISEASE*

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FOR some time past we have been interested in the diagnosis of acute abdominal disease and have used the roentgen ray particularly in connection with cases of suspected ruptured peptic ulcer. In those instances of frank pneumoperitoneum the diagnosis of perforated ulcer could generally be unequivocally established (Vaughan and Singer). However, where free air was lacking, which was frequently the case in "formes frustes" perforations (Singer and Vaughan), it was essential to concentrate upon the contour and mobility of the diaphragm in order to determine the presence or absence of subdiaphragmatic inflammation. The importance and necessity of a sound knowledge of the causes of variations in the outline of the diaphragm soon became apparent if errors in diagnosis were to be avoided. Pathologic aberrations in mobility and position and congenital anomalies were found to lend themselves readily to correct interpretation. Deviations from the normal due to physiologic variations, however, proved to be confusing and were generally misinterpreted. We were therefore led to study the available information on the subject of physiologic deformities and to scrutinize more closely the diaphragmatic contour in all cases coming under our observation.

A survey of the conventional roentgen descriptions of the diaphragm in this country indicates that normally the two halves form sharply defined, smoothly outlined arcs on either side of the heart shadow, the right somewhat higher than the left. Generally speaking, distortions in the contour of the regulation arc are considered to be due invariably to supra- and infra-diaphragmatic disease. This view is current here probably because physiologic variations are not mentioned in any of the American roentgenologic textbooks and because but scant attention has been accorded the subject in our medical periodicals. In the foreign textbooks and literature, however, wide cognizance has been taken of physiologic deformations of the diaphragm with the result that much information of practical value has been adduced.

Physiologic deviations from the classical arc simulating organic distortions are of two main types. One, the more striking, is indicated by a prominence of the anterior portion of the medial half of the diaphragm and is referred to as the anteromedial bulge (Figs. 1 and 2). This anteromedial bulge, which occurs at times under purely physiological conditions, appears also in an exaggerated form in the presence of certain intrapulmonary lesions. Related to the anteromedial bulge, from the standpoint of the mechanism involved, is the so-called tenting which occurs, however, only in the presence of pulmonary disease. On this account the phenomenon of tenting cannot be classified as strictly physiologic but will nevertheless be described on account of its relationship to the anteromedial bulge. The second type of functional variation in the contour of the diaphragm is due to hypertrophy of the constituent muscle bundles which arise from the ribs and is referred to as individualization of the costal components. The effect produced roentgenologically is a division of the diaphragm into several smaller arcs (Fig. 3) or the formation of curved bands passing to the lateral thoracic wall (Figs. 4 and 5). The latter variety of distorted contour of the diaphragm is particularly confusing unless one is acquainted with its correct interpretation.

The anteromedial bulge divides the right

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diaphragm into two arcs at a point roughly midway between the lateral thoracic wall and the cardiac shadow. This anomalous appearance may occasionally be observed under normal conditions with rapid deep inspirations. In a more pronounced form it is encountered where full or rapid expansion of the right lung is hindered as in tracheal or bronchial stenosis or in pulmonary infiltrative processes (Assmann, Plate 8, Figs. 4 and 6; also Fig. 293a). The medial arc is higher and more convex than the lateral and sagittally is seen best in slight lordosis. It disappears on bending forward. Corresponding to this, the lateral view shows the medial as a small, more convex arc in the anterior half of the right diaphragmatic shadow beginning a finger's breadth behind the sternum and ending approximately one finger's breadth posterior to the cardiac shadow (Fig. 2).

The explanation of the medial anterior bulge is found in the anatomic studies of Eisler and of Thomas. These authors ascribe the phenomenon to the varying length, strength, and position, of the component muscle bundles of the diaphragm. These may be divided into a powerful posterolateral group and a much weaker anteromedial group. The former is composed of the posterior lumbar fibers forming the crura diaphragmatici and the lateral costal fibers from the ninth rib down. This group inserts into the posterolateral part of the right wing of the central tendon. The contraction of these fibers pulls the posterolateral part very forcibly downward. In contrast, the anteromedial part of the diaphragm is depressed with relatively little force by the short fibers arising from the sternum, xiphoid and the seventh and eighth ribs. A further factor hindering the free and deep descent of the medial part of the right diaphragm, as pointed out by Assmann, is the passage of the inferior vena cava which is firmly anchored above. The

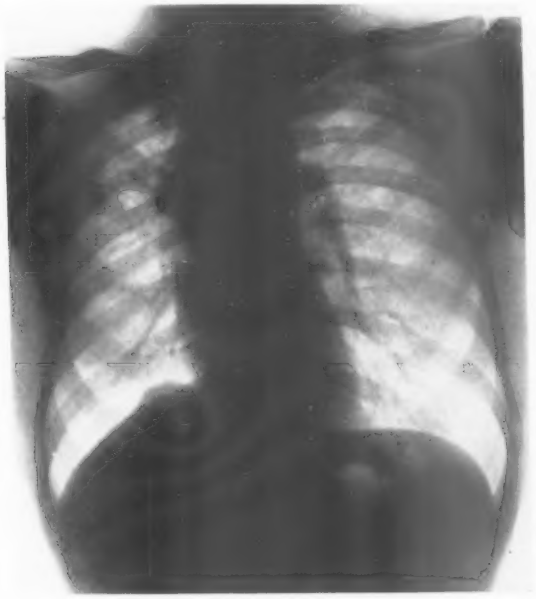

Fig. 1. Case 1. Roentgenogram of chest illustrating the anteromedial bulge. The right diaphragm shows a division into two arcs. The medial cupola is more convex and smaller than the lateral. An extensive fibrosis which involves the right upper lobe has led to displacement by traction of the trachea and upper mediastinum.

Fig. 2. Case 1. Lateral view of the same chest pictured in Figure 1. The anterior bulge is seen to commence one finger's breadth behind the sternum and to end a similar distance behind the cardiac shadow.

actual groove separating the anteromedial from the posterolateral cupola is formed by the straddling action of the strong fibers from the crus medialis joining the fibers originating from the ninth rib. The medial, smaller bulge is formed anteriorly by the short anteromedial group of muscle fibers mentioned above and posteriorly by the right wing of the central tendon. The

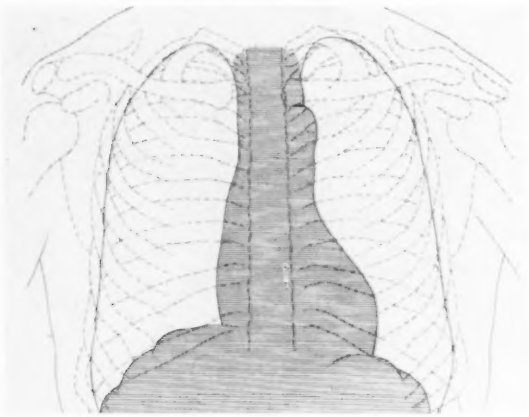

Fig. 3. Diagrammatic representation of multiple arc formation due to individualization and hypertrophy of the costal components of the diaphragm. (Taken from Rieder.[8])

larger, posterolateral cupola is formed by the powerful posterolateral group of muscle fibers previously described.

A knowledge of the aforementioned muscular components and their anatomic characteristics is of both theoretical and practical importance. From the theoretical standpoint the information is of significance since it explains why in certain instances a double contour of the right side of the diaphragm is visualized. If one bears in mind the anatomic relationships it will be readily seen how any condition which increases the negative supradiaphragmatic pressure tends to restrict the downward excursion of the weaker and less mobile anteromedial portion. Since the posterolateral division is more powerful and less fixed than the anteromedial one, the latter fails to descend as far as the former. Increased negative pressure within the chest can be produced, for example, by rapid, deep inspiration or by local obstructive or infiltrative processes which limit the expansibility of the lung. The left diaphragm is not subject to a similar change because, as Assmann points out, of the absence of a large perforating vein and the presence of a heavy structure, the heart.

From the practical side, it is of importance to be acquainted with the anatomic basis of the anteromedial bulge since it aids in differential diagnosis. The location, size and form particularly serve to distinguish it from such subdiaphragmatic lesions as encapsulated peritoneal exudates and hepatic lesions as tumor, abscess, echinococcus cyst, etc. In debatable cases roentgenoscopic examination in deep inspiration and expiration, in lordotic and kyphotic positions and in anteroposterior and lateral planes will generally lead to a correct interpretation. However, should the pulmonary fibrosis or bronchial stenosis be of such location, extent, and nature, as to cause persistence of the medial arc even in expiration, the introduction of about 200 c.c. of air will immediately cause a disappearance of the deformity (Matson) and thereby dispel any doubt.

The value in clinical medicine of a knowledge of the anatomic basis of the anteromedial bulge is illustrated in the case report which follows:

Case 1. L.Q., a dentist, aged forty-six, was admitted to the Cook County Hospital on March 14, 1932. He stated that he had, for the last thirty years, suffered from gastric complaints which at the onset were so severe as to require hospitalization. The symptoms subsided only to recur periodically with increasing intensity until 1924 when the pain became persistent. Two operations, gastroenterostomy and undoing of the anastomosis, were performed within the subsequent year. In 1927 the patient developed an active tuberculosis involving the right upper pulmonary lobe. He suffered from repeated attacks of hemoptysis which necessitated sanitarium treatment for two years, after which time the disease was considered arrested.

Recently he had suffered from an exacerbation of his previous ulcer distress. Seven days

prior to entrance he experienced an extremely violent pain in the right upper quadrant which caused him to cry out and writhe about in agony. The pain, which was knife-like in character, radiated downward and posteriorly. Morphine was required to ameliorate the patient's suffering which gradually abated and after three to four days had practically ceased. During the three days or so prior to admission the patient had felt feverish and noted sweats. The temperature upon admission was 100° F., the pulse rate 96 and the respiratory rate 24. The examination of the chest disclosed no physical evidence of activity. Aside from slight tenderness in the right upper quadrant, the abdominal examination proved negative. The leucocyte count was 11,700. The possibility of a perforated ulcer with abscess formation immediately suggested itself. The roentgen ray was therefore employed to determine the presence or absence of a subdiaphragmatic localization.

Roentgen examination of the chest showed evidence of extensive fibrosis involving the right upper pulmonary lobe. The trachea and upper mediastinum were pulled over to the affected side. Both diaphragms were freely movable but the right showed a division into two arcs (Fig. 1). The medial one was clearly more convex and smaller than the lateral. The division of the diaphragm and the relationship of the two arcs was also demonstrated in a lateral view (Fig. 2). In this latter projection the anterior bulge was seen to commence one finger's breadth behind the sternum and to end a similar distance behind the cardiac shadow. The diaphragm was, therefore, divided into two cupolas, a smaller anteromedial and a larger posterolateral one.

The significance of the anteromedial prominence was immediately brought into question. The configuration, extent and form were typical of a physiological bulge. However, the possibility of a subphrenic accumulation of exudate could not be excluded at that time. A diagnostic pneumothorax, which would have made the distinction, was deemed unwarranted. The subsequent course was depended upon to solve the problem which, indeed, it did. The clinical evidences of infection disappeared completely in spite of the persistence of the diaphragmatic irregularity. It was therefore concluded that the cause of the persistent anteromedial bulge was the fibrotic process which limited the expansibility of the right lung. The diminished expansibility increased the negative intrathoracic pressure, which in turn inhibited the downward mobility of the weakest portion of the diaphragm and forced it to encroach upon the chest cavity. The lack of distinct variation in the contour of the diaphragm with respiratory movements was explained on the basis of the rigid character of the pulmonary changes.

Another deformity, similar in mechanism to the anteromedial bulge but having no preformed anatomic basis and not strictly physiologic, as it does not occur except in the presence of pulmonary pathology, is the "pseudo-adhesion" or tenting of the diaphragm. This variation was described by Matson and ascribed by him to an acute or chronic peribronchial infiltration with loss of elasticity and expansibility. In deep inspiration, such a rigid bronchus produces a dimple on the basal surface of the lung due to the inexpansibility both of itself and of the infiltrated parenchyma about the bronchus. The diaphragm during inspiration remains apposed to this dimple due to the local increased negative pressure with formation of an upward directed tent-like deformity. Here, also, resolution of the process if acute or the introduction of a little air in the pleura in chronic cases effects a return of the diaphragm to its normal, arc-like shape. Even saucer-shaped deformities simulating subphrenic abscess have been described due to the same mechanism (Middleton).

The second main type of contour deformation, described as individualization of the costal components, depends upon the variable development of the muscle bundles arising from the lower six ribs. In general, the component fibers form a continuous smooth sheet giving the diaphragm the appearance of a single, uniform arc. However, in certain instances the costal bundles form distinct, thick, band-like digitations which modify the outline of the diaphragm causing the latter to break up into multiple small arcs (Fig. 3) or to form a series of step-like extensions to the chest wall (Figs. 4 and 5). The relation of these diaphrag-

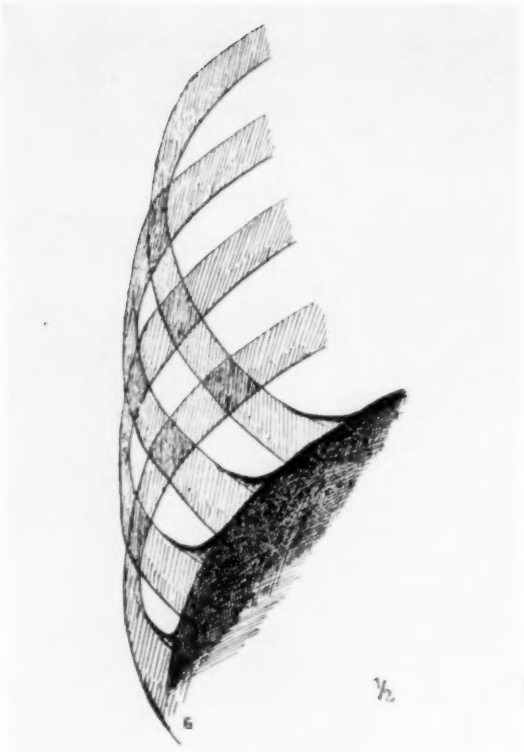

Fig. 4. An oblique view showing the relationship of each of the step-like diaphragmatic extensions to the individual ribs. (Taken from Fleischner.[5])

matic muscle bands to the parallel sagittal grooves found at post mortem on the anterior and superior surfaces of the liver has long been a matter of dispute. As early as 1900 Chiari could review a dozen or more theories to all of which Westenhöfer has recently made objection. In a recent article by Weltz the relationship of the knobby diaphragm to the liver furrows encountered at autopsy is stressed. Whatever the effect on the liver may be, the fact remains that the costal components may form distinct muscle bundles. These bundles are not parallel, as is generally believed, for they normally cross and interlace (Eisler, Thomas).

The division of the diaphragm into multiple arcs has been frequently observed and carefully studied, especially by continental roentgenologists. Rieder, Schinz, Baensch and Friedl, Assmann, as well as others, have pointed out that the right dome and to a lesser extent, the left, may break up into several smaller arcs during the height of inspiration, i.e., during maximum contraction of the decussating muscle bundles. The phenomenon is ascribed to individualization and hypertrophy of the separate costal bundles. The causes of this excessive muscular development are being investigated. Rieder has observed that a scalloped appearance of the diaphragm is frequent in athletes and in compensatory hypertrophy of one diaphragm in the presence of disease of the other. Weltz has found the incidence of diaphragmatic folds to be high among individuals suffering from asthma, emphysema and chronic bronchitis. This author concludes from his observations that the barrel form of the chest produces either a passive tension and distortion of the diaphragm, or a persistent muscle hypertonus. Differentiation from adhesions can be made by noting in cases

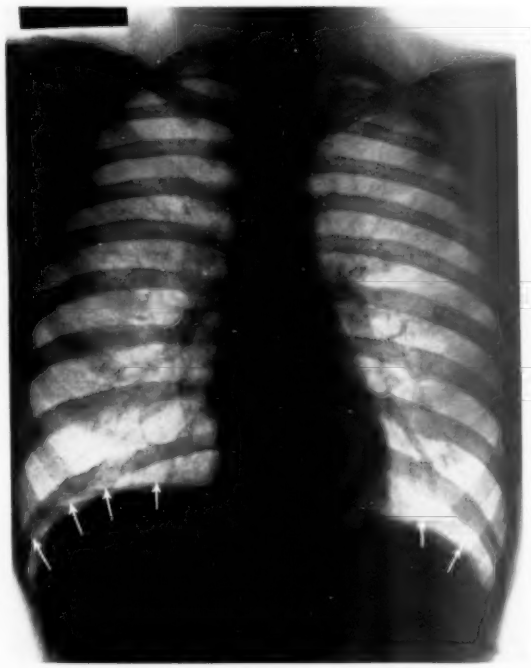

Fig. 5. Case 11. Roentgen appearance of the chest during inspiration. The series of digitations due to individualization of the costal components of the diaphragm are indicated by arrows.

of hypertrophy of the costal muscle bundles, disappearance of the irregularity with expiration. Also one observes that whereas in adhesions the apices of the arcs are directed upward, in functional distortions of the diaphragm the apices between the individual scallops point downward.

The second form of variation which results from individual hypertrophy of the separate costal bundles is the actual visualization of these digitations illuminated in the costophrenic angle on deep inspiration. The phenomenon was apparently first recognized by Fleischner as a step-like irregularity in the lateral diaphragmatic contour (Fig. 4) and was properly interpreted by him. He was able to demonstrate, in two patients who subsequently were subjected to artificial pneumothorax, that the lateral diaphragmatic ridges were not adhesions. Weltz observed the same diaphragmatic variation in his cases of asthma, emphysema and bronchitis. He considered the knobby or scalloped deformity of the diaphragm a counterpart of the step-like, lateral ridge formation and attached the same significance to both phenomena. The curved bands passing to the lateral costal wall representing individual digitations are seen only upon deep inspiration and can thereby be distinguished from adhesions. The error can be easily avoided, according to Fleischner, by noting the multiplicity and regularity of the steps and their relationship to the ribs.

The costal digitation or multiple ridge deformity of the lateral portion of the diaphragm, although not uncommon, is recognized by very few. Fleischner who described it, stated in 1931, that in spite of its frequency, it appeared to be unknown. Weltz, who in 1932 found outspoken contour variations due to hypertrophy of the costal bundles in 59 of 100 asthmatics examined, mentioned no other author than Fleischner in connection with a discussion of the step-like variety. Both of the above observers submitted diagrammatic representations of the costal digitation deformation but neither of them published actual reproductions of roentgenograms. It was our good fortune to encounter recently a case in which the muscular digitations were well visualized and to secure a satisfactory plate demonstrating the roentgenoscopic picture. Since this type of contour irregularity, so far as we have been able to ascertain, has not been described in this country, a presentation of the chief features of the case appears warranted.

Case II. A white woman, aged thirty, complained of lassitude, ready fatigue and failure to gain in weight. Examination disclosed a thin, tall, asthenic woman, with no physical abnormalities other than an obvious visceroptosis. Upon roentgenoscopy of her chest, step-like upwardly concave bands were seen bilaterally (but more on the right) crossing the costophrenic angle, appearing on deep inspiration (Fig. 5) and disappearing with expiration. Each band appeared distinctly related to a separate rib. In view of the symmetrical, bilateral character and the absence of any immobilizing or distorting effect on the diaphragmatic arcs, these bands were considered to be abnormally hypertrophied, diaphragmatic digitations rather than costophrenic adhesions. This interpretation was concurred in by Professor Kampmeier of the Department of Anatomy of the University of Illinois, College of Medicine. Very likely the low diaphragm associated with the asthenic habitus and ptosis aided in rendering these digitations visible. Anatomically the visualized bands would correspond to well-defined muscle bundles lying in those deep, sagittal liver grooves of Liebermeister which were discussed above.

SUMMARY

Physiologic variations from the classical arc which simulate organic distortions can be conveniently separated into two main groups. In one, the prototype is indicated by a prominence of the anterior portion of the medial half of the diaphragm and is referred to as the anteromedial bulge. This variation occurs under purely physiologic conditions but appears also in an exaggerated form in the presence of certain intrapulmonary lesions. Related to the anteromedial bulge from the standpoint of mechanism is the so-called tenting which

occurs only in the presence of pulmonary disease. The second type of functional variation in the contour of the diaphragm is due to hypertrophy of the constituent muscle bundles which arise from the ribs and is referred to as individualization of the costal components. The effect produced roentgenologically is a division of the diaphragm into several smaller arcs or the formation of curved bands passing to the lateral thoracic wall.

Two cases are reported illustrating the two main types of physiologic variation. The first case was one in which the history was characteristic of a perforated ulcer and the distortion of the diaphragm compatible with the presence of a subphrenic or intrahepatic abscess. A knowledge of the distinctive features of the anteromedial bulge led to a differentiation which subsequently proved correct. The second case was one of a visceroptotic woman in whom the individual digitations were well visualized roentgenologically in the costophrenic angle. This latter case assumes importance in that individualization of the costal components has not heretofore been described in the American literature and as far as can be ascertained no actual roentgenogram has been previously published.

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PULMONARY CHANGES IN A CASE OF PERIARTERITIS NODOSA*

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PERIARTERITIS nodosa is a rather rare arterial inflammatory disease. Males are affected more frequently than females, the proportion being about 87 to 26 as shown by reported cases. It may occur at any age but is more common in the third decade. Some authors still consider the infecting organism as being unknown, attributing the disease to a filterable virus, while others believe that clinical observation and animal experiments have proved it due to streptococcic septicemia.

Pathologically, the disease is characterized by marked cellular infiltration with granulation tissue formation in and about the arterial walls of the medium and small sized arteries, with a varying degree of intimal proliferation. Necrosis of the media usually accompanies these changes. These pathological processes may be grouped into four stages.

The first is characterized by edema and thready, fibrinous exudation about the elastica intima with muscle walls separated by the exudate.

The second stage of exudation shows infiltration of the media and adventitia by polymorphonuclear cells, with necrosis of the vessel wall following. At the height of this stage, secondary thrombosis with infarction of the organs involved occurs, followed by rupture of the vessel or aneurysm. Hemorrhage into the adventitia or surrounding tissue may accompany these processes. No suppuration takes place as a rule. In this stage we find high fever and chills, and death is not infrequent.

In the third stage, we find proliferation of the intima with partial or total occlusion of the lumen.

The fourth stage is the healed or regenerative stage where considerable fibrous scar tissue is found with cells quite poor in nuclei. Narrow channels are found running through greatly thickened arterial walls.

Clinically, the disease may be difficult to diagnose, particularly in the early stages, since symptoms may be confined to the principal organ involved. The disease itself may be confined to the artery supplying one organ or one portion of the body. In general, we find the following: Temperature is always elevated; there is a leucocytosis with definite increase in the polymorphonuclear cells; occasional eosinophilia is found; urine usually shows albumin and hyaline casts because arteries of the kidney are very commonly involved. There is usually abdominal pain. Frequently arthritis is present and a peripheral neuritis may occur, and when present, should make the possibility of periarteritis nodosa one to be seriously considered. Some cases have sore throat and some may have asthmatic attacks. Arkin says that the kidneys are involved in 80 per cent of cases, heart in 70 per cent, liver in 65 per cent, gastrointestinal system in 50 per cent, pancreas in 25 per cent, mesenteric arteries in 30 per cent, arteries supplying muscle tissue in 30 per cent, and peripheral nerves in 20 per cent. He does not mention pulmonary blood vessels at all. Inasmuch as the symptoms in different cases of periarteritis nodosa are so dissimilar due to the varying organs that may be involved, the following diseases among others must be considered in differential diagnosis: typhoid fever, peripheral neuritis, myositis, miliary tuberculosis, dysentery, meningitis, and encephalitis. Where single regions are involved, the symptoms of course may be those of any disease referable to the particular organs involved.

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Where peripheral blood vessels are involved, small nodes may be felt along the course of the artery. These may be single or the blood vessel may be beaded. Many cases of course go unrecognized until autopsy. There is a high mortality in this disease unless there are cases which go

FIG. 1.

unrecognized and recover. Duration of the disease may be six days to two years; average length is four to seven months.

We are presenting the following case because, so far as we have been able to find in the literature, there has been no case reported in which periarteritis nodosal changes in the arteries of the bronchi or the pulmonary tissue have been recognized by the roentgen ray. In fact, Arkin does not even mention pulmonary vessels as being involved. He does mention several cases which developed pneumonia in the course of the disease, or hemorrhagic infarction. One case showed atelectasis of both lower lobes with emphysema of the upper lobe. Ophüls reports a case in which roentgenoscopic observation of the chest showed pathology involving both apices and fixation of the left diaphragm. Autopsy showed that some of the bronchial arteries had a definite periarteritis and endarteritis with destruction of the media of the pulmonary arteries. There were small areas of bronchopneumonia. There was a diffuse infiltration of the bronchial tubes with eosinophilic leucocytes similar to that commonly observed in asthma. Smith also reports a patient who suffered from asthma. In this case, there was extreme involvement of the small branches of the pulmonary artery. Bronchial arteries have been found involved in some cases but pulmonary arteries only rarely. Mönckeberg is the only other author who has described similar lesions of the lung. In all, there are about 150 cases reported in the literature.

REPORT OF CASE

Patient white, female, aged forty, entered the hospital on June 30, 1930, with the following history: Four weeks previous to admission she began to have pain in the left shoulder with radiation down the arm; has had hacking cough which she called "cigarette cough"; no hemoptysis; history also of afternoon rise in temperature, night sweats, loss of weight, loss of appetite. Three days prior to admission patient felt numbness on the extensor surfaces of both feet. Following this she developed numbness of both feet and loss of motor function, more marked on the right than on the left. Past history negative. Temperature on admission was 102.6° F., pulse 120, respiration 30.

Physical Examination. Essentially negative except for evidence of what appeared to be a polyneuritis involving both lower extremities, more marked on the right than on the left.

Laboratory Findings. Urine showed a trace of albumin but otherwise was negative. Blood count showed a leucocytosis of 22,000; 4,100,000 red cells. Blood and spinal fluid Wassermann negative. Blood culture negative.

On July 2, 1930, three days after admission, roentgenograms were taken of the chest, which were negative, no evidence of pulmonary pathology being noted. Physical examination of the chest at this time was also negative. The teeth were also roentgenographed and found to be negative for apical or root infection. Neuro-

logical consultation was obtained and the impression was that the condition was one of infectious polyneuritis. Patient became gradually worse and on August 6 was definitely weaker, had a temperature of 102° F., pulse 140, was dyspneic and cyanotic. On August 11, a roentgenogram (Fig. 1) was taken of the chest which showed a diffuse perivascular infiltration spreading out uniformly and equally from both hilar regions; involvement apparently stopped very definitely and symmetrically at the midclavicular line on both sides. In the perihilar regions there were areas that might be considered as representing either small infarctions or small areas of bronchopneumonia, or both, around which there was pulmonary congestion. Appearance was more that of a vascular condition than of any pulmonary infection. At about this time, she was seen by Dr. Wiener who made a diagnosis of periarteritis nodosa because of the progressive muscular dystrophies, myocardial changes, pulmonary phenomena as observed by the roentgen ray, peripheral nerve involvement and acute nephritis which is nearly always present in these cases.

The patient's condition remained practically unchanged and subsequent roentgenograms were taken on August 13 and 18. On August 13, the condition appeared about the same except that there was more evidence of intravesicular and peribronchial or vascular exudation. Although these marked pulmonary changes were observed roentgenographically, physical findings in the chest continued to remain practically negative. On August 18, the fine, discrete, linear markings were becoming confluent, indicating further exudation, with suggestion of beginning solution or cavitation here and there.

Patient left the hospital on August 18, 1930, against the advice of the physician. She was readmitted to the hospital on October 13, 1930, at which time she was in a semi-moribund state. At this time she showed evidence of involvement of the cerebral blood vessels and developed a hemiplegia. Condition became gradually worse and patient died on October 25. Ante-mortem roentgenogram was taken, October 14, 1930, but due to the patient's clinical condition, films were quite unsatisfactory for giving any impression as to lung detail. They did apparently show infarction and effusion. Also the impression was obtained that some of this perivascular exudation was being absorbed, and while in some regions there was destruction of lung tissue, in others there was a tendency to resolution of the process. Post-mortem roentgenogram showed fluid in the right chest which totally obscured the lung markings. On the left side, some of the pathology previously noted was apparent around the left hilus, much less marked, with the rest of the left lung aerating.

Fig. 2.

Autopsy Report. White, adult woman, approximately thirty-five years of age. The body was rather wasted. There was a uniform pallor of the entire body. The face showed a peculiar brownish pigmentation. This was observed to be irregularly distributed throughout the body. The entire lower extremity on the right side showed a uniform edema although the leg was flabby. The lower extremity showed marked dystrophy of the muscles. The wasting was very marked. Upper extremities: The musculature was extremely flabby but the dystrophy of the left side was very marked as compared with the right. There was hypertrichosis of the chin and upper lip.

The right pleural cavity showed a straw-colored fluid, the specific gravity of which was 1.014. There were some flakes of fibrino-purulent exudate, the amount of which was roughly 750 c.c. The pleura was markedly congested and fibrino-purulent in places. There was fibrin-

ous exudate between the right pleura and the pericardium.

The lungs showed a number of infarcts, at least 60. Some of them were very large and they were hemorrhagic in type. Some showed considerable breaking down. The vessels of these infarcts seemed thrombotic. The left pleural

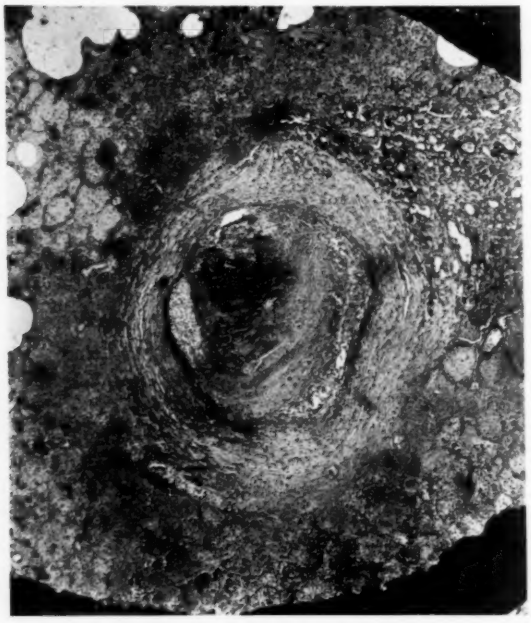

FIG. 3.

cavity showed no fluid. Scattered in both lung fields were a few isolated tubercles, but there apparently was no active pulmonary tuberculosis. No definite pathology in the pleura.

Pericardium: There was about 115 c.c. of straw-colored, clear fluid in the pericardial sac. No definite pericarditis. The heart did not show any worthwhile pathology except that at the apex anteriorly we felt a definitely uneven surface on palpation of the terminal portions of the coronary vessels. The leaves of the coronary artery, and the aorta itself, showed no definite pathology.

The liver appeared to be smaller than normal. The surface after removal of the capsule was quite granular. The organ cut with an increased resistance. We believed we were dealing with an early atrophic cirrhosis of the liver.

The stomach, gallbladder, and pancreas, showed no definite pathology except for nodules along the cystic artery.

The spleen showed no definite pathology.

The kidneys were about normal in size, showed no infarctions, but the surface showed a number of petechiae, with periarterial nodes along the branches of the left renal artery.

The genitourinary tract: Uterus of normal size. Fallopian tubes showed chronic adhesions around them, and superimposed on the upper surface of each Fallopian tube were found a few hard tubercles which looked like a tuberculous process.

Cultures taken from the heart, showed staphylococcus; from the spleen, streptococcus.

Microscopical slides of the kidney (Fig. 2), heart, including the coronary blood vessels, and the lungs (Fig. 3), showed multiple and diffuse nodosities of periarteritis. In the lung these changes involved both the bronchial and pulmonary vessels; in fact, the entire arterial tree showed this pathology. These findings were confirmed by Dr. W. G. MacCallum of Johns Hopkins Hospital.

Diagnosis: Streptococcic septicemia; multiple infarcts of the lungs; chronic pleuritis; right hydrothorax; atrophic cirrhosis of the liver; chronic tuberculous salpingitis; periarteritis nodosa. (C. A. Pons, M.D., pathologist.)

In all cases where periarteritis nodosa is suspected clinically, we believe it would be advisable to make serial roentgenographic studies of the chest. It cannot be determined from one case that the changes here reported are characteristic of periarteritis nodosa. While intrathoracic blood vessels are not as commonly involved as is the vascular system in other locations, there are, nevertheless, a number of cases reported in the literature with respiratory symptoms, and in this particular case, respiratory symptoms subsequently developed but were not prominent early in the disease. It is our impression that the pulmonary changes noted in the lung in this patient, roentgenographically, were due to vascular and perivascular inflammation and exudation, together with associated congestion and small infarcts. The definite and persistent limitation of the changes noted to the inner one-half of both lung fields is at least consistent with the fact that only the arteries of a given size, i.e., moderate size, are, as a rule, involved.

We offer this case with the hope that

other investigators will report whether or not these apparently characteristic changes are repeated in other cases where there is pulmonary involvement.

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POST-TRAUMATIC CYSTIC DISEASE OF THE CARPAL BONES

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PRACTICALLY every physician making roentgenograms of many injured and painful wrists has found cases showing changes in the structure, size, and shape, of one or more of the carpal bones, particularly the semilunar and navicular. There is a general impression that this condition is rather rare, chiefly, I think, because of the infrequency of reports in the literature, the latest American references found being those by Buchman,[2] Goldsmith,[3] Henderson,[4] Patterson,[8] and Voshell.[11] It is my opinion that if all the cases were collected and given a standard diagnosis the number would be rather large. The diagnoses made of this condition have been many, the most common of which are Kienböck's disease, secondary post-traumatic malacia, traumatic osteoporosis, osteodystrophia cystica, traumatic malacia, and chronic osteitis. A descriptive diagnosis would seem to be preferable, but the variability in stages of progression and terminal states makes it difficult for one term to fit all accurately; that of post-traumatic cystic disease seems fairly all-inclusive, but not very sharply defining. The most widely used name at the present time is that of Kienböck's disease, though Preiser has apparently done more towards working out the etiology and delineating the disease than Kienböck.

In 1910 Preiser[9] reported 5 cases of an affection of the navicular bone following injury, which first showed multiple cystic rarefactions and terminated in a picture resembling an ununited fracture. Kienböck[6] later in the same year described a condition of the semilunar bone the nature of which was a structural change, some of the cases having suffered a primary fracture. There was an alteration in shape with a decrease in size, and an increase in density of the bone.

Due to the fact that the greater number of Preiser's cases are limited to the navicular, and those of Kienböck's to the semilunar, together with the observation that the lesion in the semilunar usually progresses from a softening and porosis to a sclerosis while the navicular involvement shows progressive cystic changes which persist and usually result in fracture, if it had not already occurred at the time of the original injury, some consider that the two are separate clinical entities. Baum[1] feels that the conformity of the pictures, as described by Preiser and Kienböck, from the clinical, roentgenological, and anatomical viewpoint, justifies the assumption of the same etiology. This was concurred in by Kienböck in his original article.

That the two lesions are identical as to etiology, there can be little doubt. The history of onset is the same in all cases, as are the roentgen findings at least in the first stages. Three of my cases show a cystic involvement of both bones, the pathology being the same except for a fracture of the navicular in two of them in addition. A fourth case shows the process limited to the navicular and corresponding to the original description of Preiser's,[9] while the fifth shows a cystic change of only the semilunar that terminated in a sclerosis as described by Kienböck.[6] Why there is a variation in the terminal stages in the lesions of the semilunar is a matter of conjecture. The type of fracture, occupational trauma, degree of injury, and amount of restoration of blood supply, probably all play a part.

The etiology seems to be a primary injury to the wrist, which according to Müller[7] may be of three types: either (*a*) abnormal pressure resulting from associated anomalies, (*b*) repeated minor occupational injuries, or (*c*) severe trauma. The

opinions as to the nature of the injury are somewhat variable but in general agree upon a disturbance in nutrition. Preiser[10] assumes that the process is a result of detachment of the ligamentum naviculolunatum which contains the main nutrient vessel and describes a case which showed small areas of rarefaction a few days after injury that entirely disappeared in the course of a few weeks, his inference being that the nutrition was restored through collateral circulation. Kienböck feels that the condition follows a subluxation, either partial or complete with spontaneous reduction, causing destruction of the blood supply, followed by nutritional disturbances, which result in a gradual disintegration and fragmentation of the bone. Kappis[5] thinks the cause is a crushing and avulsion of the ligaments carrying the nutritive vessels, but he also says interosseous hematomas may lead to the same result. Wollenberg[12] differs from the others in that he feels that all cases suffer at least an infraction of the bone, and upon this old fracture a process develops which should be grouped under the heading of localized osteitis fibrosa. Baum disagrees with Wollenberg over the interpretation of the microscopic findings. In his opinion they show a cellular infiltration in areas of necrotic anuclear osseous and cartilaginous trabeculae which has the appearance of being a reaction to unusually extensive aseptic bone necrosis. His interpretation is that the fracture resulting from the primary traumatism heals in part by pseudoarthrosis, and also by greatly delayed or incomplete production of callus. It does not seem credible from the etiological and roentgenological findings that there is an inflammatory or infectious element in this condition. The interpretation of Baum I believe should be accepted until proved wrong by further microscopic examinations. Most authors referring to this affection as an osteitis, however, appear to be taking the term in a broad sense, implying an aseptic infiltration followed by sclerosis. Even though this is the case I believe the term should not be used as it is rather misleading.

The differential diagnosis involves the elimination of a large number of conditions, but should not be difficult for a trained roentgenologist. The diseases to be considered are tuberculosis, arthritis, syphilis, osteitis fibrosa, congenital bone conditions, central bone abscesses, tumors, and deceptive pictures caused by superposition.

Fig. 1. Case 1. Navicular and to lesser degree semilunar show multiple small cystic areas with marginal increase in density. Navicular and to lesser degree the radial articulating surface show arthritic changes.

The course of the disease is rather variable depending somewhat upon the type and nature of the injury. After an injury, usually of sufficient degree to produce at least transitory pain, and a disturbance of function, the individual is often comparatively free from symptoms for a period of a month or months, when without apparent cause the wrist becomes painful to pressure, especially over the semilunar, with some swelling of the wrist and limitation of motion. This continues with periods of

FIG. 2. Case II. Navicular and semilunar show multiple cystic areas varying in size. Questionable narrowing of semilunar in vertical dimension, old fracture of navicular. Marked irregularity in articulating surface and density of distal end of radius, no history of fracture.

exacerbation and regression, which show no particular relationship to the use of the wrist. A factor of importance in this secondary stage of pain and disability that must not be overlooked as at least an accessory element is that all advanced cases show a varying degree of arthritis as evidenced by irregularity in density and articulating surfaces of the radius and the carpal bones.

The treatment is not very satisfactory and depends upon the stage of progress when discovered. Conservative treatment in the early stages in the form of rest, heat, and massage, leads to a good result or at least a workable wrist in about half of the cases. The experience of nearly all writers has been that where the fracture is followed by pseudo-arthrosis and a cystic degeneration or fracture follows the cystic change, union very rarely, if ever, takes place. In these cases the only treatment is either partial or total extirpation. The results from operation do not give an absolute restoration of function but can be considered successful in at least half of the cases. Müller reports complete recovery in a case in which he did an evacuation of calcium and bony débris with preservation of the actual bone shell.

As mentioned above it has been my privilege to have 5 of these cases, the primary films on one of them (Case V) being furnished me through the courtesy of Dr. J. V. Prouty. I wish to present briefly the case history of each with accompanying remarks.

CASE I. J. K., coal miner, aged twenty-nine. Injured right wrist in 1920 while boxing. Primary symptoms lasting a few days. Almost a year later wrist became painful and has bothered him ever since, being worse at intervals. Examination reveals localized tenderness over navicular, slight limitation of extension and flexion, and a mild swelling of wrist. For roentgen findings see Figure 1. The chief points of

FIG. 3. Case IV. Marked cystic change in navicular with old ununited fracture. No abnormal findings in semilunar. Navicular and styloid of radius show arthritic changes.

interest here are, the involvement of both navicular and semilunar bones, the arthritic changes, especially in the navicular, and the fact that though the condition is ten years old there has been no definite fracture and the cystic areas are not as large as seen in other cases of shorter duration. The question arises, therefore, as to whether the degree of bone change is not in direct proportion to the amount of blood supply injury.

Case II. H. T., foundry worker, aged twenty-eight. Fractured navicular bone of right wrist in 1925 at which time there was no change in bone texture. Wrist has troubled him ever since being worse at times and swollen in proportion to the pain. For roentgen findings see Figure 2. The salient findings here are, the almost identical cystic changes in navicular and semilunar with a fracture of the navicular and questionable narrowing of vertical dimension of the semilunar, also the fact that we can prove the cystic changes followed the injury.

Case III. H. W., coal miner, aged thirty-two. Injured right wrist in July, 1930, at which time roentgen examination was made showing fracture of the navicular, but no change in bone texture. An operative tendon repair on the dorsal aspect of the wrist was made a month later. Roentgen examination a year later shows almost identical findings with those of Case II. Wrist has been continuously painful since injury with no improvement. The important fact here is the production of a condition in one year almost identical with that found in Case II which is of six years' duration.

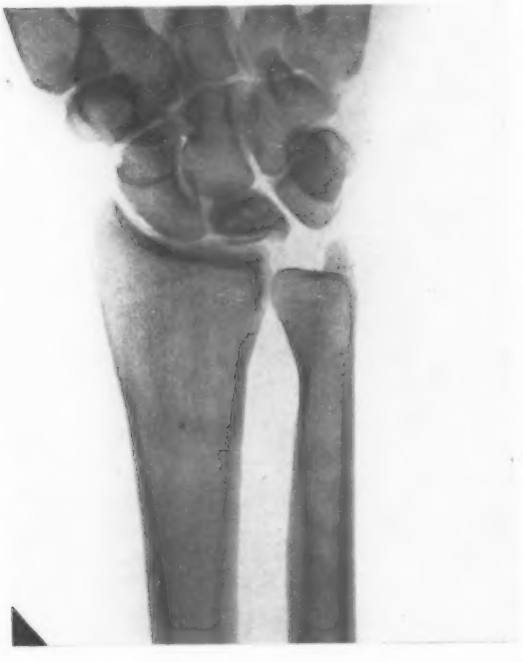

Fig. 4. Case V. Marked decrease in size of the semilunar, with some increase in density about multiple cystic areas. Outline of bone and articulating surfaces of semilunar and radius quite irregular.

Fig. 5. Case V. Not much change in size of the semilunar, but an increase in density with loss of cystic areas. Several small free bony fragments are visualized. Arthritic change of navicular and styloid of radius present.

Case IV. V. J., laborer, aged thirty-six. Injured right wrist in 1917 while in the army when he fell backward onto his hands. Since that time wrist has been painful, becoming aggravated at times without apparent reason. He has not injured it since but thinks local swelling is becoming greater. Roentgen examination made May 14, 1931 (Fig. 3). This case appears to fit those originally described by Preiser.

Case V. C. S., mechanic, aged twenty-eight, left handed. Injured left wrist in 1922, after which it pained him considerably, never being entirely free from pain, and having intervals of exacerbation. In May, 1929, injured again when wrench slipped and hand struck a steel structure. See Figure 4 for roentgen findings. In

September, 1929, wrist was operated on and portion of bone removed, the surgeon reporting bone as necrotic and friable. In October, 1931, injured wrist again. See Figure 5 for roentgen findings. Has never been entirely free from pain. One must not lose sight of the operative procedure in drawing conclusions as to this case, but I believe no one will question the diagnosis.

After a study of these cases and the literature upon the subject, I wish to offer the following conclusions:

1. That the conditions as described by Preiser and Kienböck are not separate clinical entities. This, of course, is not an original observation but is something that has been lost sight of by some writers.

2. That a standard diagnostic name should be adopted, the most inclusive one up to the present time being "post-traumatic cystic disease of the carpal bones."

3. That the disease is much more common than the literature would indicate.

4. That the arthritic element as a factor in the production of pain must not be overlooked in these cases.

5. That the term osteitis should not be used in connection with this condition, at least not without qualifying it.

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TUBERCULOSIS OF THE DIAPHYSIS*

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CASE reports of tuberculosis of the diaphysis are comparatively rare. Of these infrequent lesions the hypertrophic form is more common. The following case, that of a destructive lesion in the fibula, is an example of the extremely uncommon occurrence of a destructive tuberculous lesion confined to the shaft of a long long bone.

The patient, a white male, aged seventy-six, was admitted to the Underwood Hospital, Woodbury, N. J., August 4, 1930. His chief complaint was a tumefaction of the outer side of the left leg. The family history was unimportant, likewise his personal history, except for an attack of pleurisy with resulting empyema, in July, 1929. A thoracotomy was performed and recovery was rapid. Previous to his admission, he had been treated in another hospital for the tumefaction of the left leg, and he stated that a diagnosis of bone cancer had been made and amputation was urged.

Roentgenographic examination of the left leg (Figs. 1 and 2) showed a destructive lesion in the middle of the shaft of the left fibula. A diagnosis of a localized low grade osteomyelitis was made. The Wassermann reaction was negative. The tumor was aspirated and a cloudy, straw-colored fluid was removed. Both smears and cultures were negative for organisms. A small portion of the fluid was injected into two guinea pigs. After six weeks, tubercle bacilli were found in abundance in these animals at the site of the injection, in the lymph nodes, spleen, liver and lungs. On September 18, 1930, operation (Dr. J. H. Underwood) was performed consisting of a deep incision with removal of all necrotic tissue and rough bone. Healing was prompt and fourteen months later there had been no recurrence.

Pathological report of excised specimen (Dr. David Farley): "Gross specimen consists of a number of villous-like fragments of tissue. Some of the fragments are covered by what appears to be purulent exudate. Fragments are

FIGS. 1 and 2. A superficial, circumscribed area of rarefaction in the middle of the shaft of the fibula. There is no surrounding zone of increased density, nor is there any periosteal reaction. The lesion is entirely destructive in nature.

composed of cartilage and fibrous tissue. On microscopic examination, the lesion is that of tuberculosis."

A few months later, a localized swelling developed at the right elbow. The patient at that time was living in western Pennsylvania, and roentgen examinations made there showed a destructive lesion in the lower end of the humerus. This was drained on May 4, 1931, but no laboratory reports or pathological confirmation of the tuberculous lesion could be obtained. In September, 1931, the wound in the right elbow was still discharging, and the patient re-

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ported that his health was becoming steadily impaired.

HISTORICAL REVIEW

According to Vignard and Mouriquand, Boyer (1803) gave the first anatomical description of spina ventosa of the long bones but he described it as existing only in the short long bones, and his description did not seem to be that of tuberculosis. Nélaton (1837) affirmed the tuberculous nature of spina ventosa and Rognetta, at approximately the same time, described a chronic medullitis of the long bones. Varanguien de Villepin (1842), inspired by the work of Rognetta, described spina ventosa, not only of the fingers and metacarpals but also in the long long bones. Parrot (1880) presented an autopsy of a child dead of convulsions with a tuberculous lesion in the second metacarpal and two additional lesions in the ulna. In 1880 he reviewed the literature and reported another case of tuberculosis of the lower third of the fibula.

Koenig (1884) gave one of the first complete résumés of tuberculosis of bones and joints. Kolodny (1925) wrote: "The pathology of skeletal tuberculosis would be an entirely unknown field if it were not for the studies of the orthopedic and the general surgeons. To the clinician more than to the pathologist we are indebted for the clearing up of this important field. The work of Volkmann, F. Koenig, F. Krause and N. Senn is still to be considered as authoritative, in spite of the twenty-five to forty-five years since it was done."

Numerous case reports of tuberculous lesions located in the diaphysis, usually of the hypertrophic type, have been reported

FIGS. 3 and 4. Marked periosteal proliferation of the middle of the shaft of the left femur in a child three years of age. Blood and spinal fluid twice negative. Disseminated tuberculosis found at autopsy. No pathological sections were cut from the involved portion of the femur and the diagnosis of tuberculosis of the shaft thus had no absolute verification. This case was reported in detail previously.[4a]

in the German and French literature. Fraser and Stiles have found the condition frequently in their clinics in Edinburgh. Allison and other writers have reported cases in America. However, American roentgenologic journals contain few references to diaphyseal lesions of tuberculosis, and, though rare, they must always be considered as a possibility by the roentgenologist when confronted with an obscure lesion of the shaft. In 1899, Küttner stated that the two most serious surgical bone diseases, acute osteomyelitis and tuberculosis, are distinguished by the fact that tuberculosis affects the spongy portions of the bone and osteomyelitis affects the shaft; but that exceptions to this rule occur and that if one depends upon it, mistakes in diagnosis will result. He quoted Bruns who found the shaft affected in 6 out of 2,127 cases of bone tuberculosis, only 0.28 per cent.

PATHOGENESIS

Tuberculosis of the long bones may be divided into two main groups according to the location of the lesions: (1) in the diaphyso-epiphyseal region and (2) in the diaphysis. The former group is certainly much more prevalent. This seeming predilection for growth of the primary tuberculous focus in the spongy portions of the bone has led to controversy over the questions of pathogenesis and etiology. Numerous theories for this predilection have been offered.

Nélaton. The red marrow begins to change into yellow at the end of the first year of life and the metamorphosis is complete at the fourteenth to the sixteenth year. The red marrow persists longest in the short long bones and in the spongiosa of the long long bones, hence the location of the majority of tuberculous foci in the latter because of the predilection of the tubercle bacilli for red bone marrow.

Koenig. The first suggestion of an embolic theory of skeletal tuberculosis was made by Koenig (Kolodny). He was influenced in this belief by the frequent wedge-shaped form of sequestra. The tubercle bacillus brought in by the blood stream stops at a narrowing or a blind ending of a capillary, and a tubercle results.

Lexer showed in 1904 that the capillaries of the nutrient artery of the diaphysis

Fig. 5. Extensive periosteal proliferation and thickening involving the upper half of the diaphysis and the metaphysis of the ulna. Multiple tuberculous bone foci elsewhere in the same patient.

FIG. 6. Large elliptical-shaped area of rarefaction in the metaphysis and diaphysis with an oval area in the epiphysis of the lower end of the femur in a child aged three and one-half years. Old tuberculin, 0.1 mg. strongly positive after twenty-four hours. Clinical course of the disease typical of tuberculosis of bone and knee joint.

of the metaphyseal vessels close to the diaphyso-epiphyseal junction of the rami perforantes of the epiphysis and finally of the epiphyseal vessels of the ossification center as well as end arteries which surround the joint cartilage do not anastomose but are end-vessels in the sense of Cohnheim. The finer ramifications of these diaphyseal, metaphyseal and epiphyseal arteries are directed toward the epiphyses, and this partially explains the location of the primary foci in tuberculosis of the long long bones, i.e. more often in the metaphyseal and epiphyseal areas than in the diaphysis.

Kolodny (1925) by his anatomic studies supported his hypothesis that if the hematogenous-embolic theory is correct, then certain anatomical facts should govern the location of the lesions in the ends of the bones, metaphyses and epiphyses. Thus, anatomical findings, which he describes in detail, govern the location of foci so often found, for example, in the lower angle of the head of the femur and the anterior aspect of the vertebral body, and also, there are anatomical reasons for the extremely rare, if ever present, location of foci in the subtrochanteric fossa of the neck of the femur or the posterior aspect of the vertebral body.

Ely opposed the embolic theory and suggested a theory of pathogenesis based on the known specific affinity of the tubercle bacillus for epithelial, endothelial and lymphoid tissue, that is, the red bone marrow of the epiphyses and synovia of the joints. The existence of diaphyseal forms of tuberculosis has been definitely proved, which seems to refute Ely's argument that

his theory explains the question: Why are primary foci of tuberculosis of bone found in the epiphyses while in suppurative osteomyelitis the shaft is involved?

Payr states that *Staphylococcus pyogenes aureus* has the tendency and ability to cause thrombophlebitis and during the transfer of large, soft blood clots, larger blood vessels are clogged quite easily, hence in pyogenic osteomyelitis the larger blood vessels of the shaft are affected.

PATHOLOGY

The various authors writing on shaft tuberculosis differ in their classification and terminology of lesions and also in their answer to the question: What constitutes diaphyseal tuberculosis? Thus Küttner divides shaft tuberculosis into primary from the cortex or marrow canal, and secondary from the epiphysis. Caan agrees with Hildebrandt and Zumsteeg that cases should be counted as shaft tuberculosis which start in the metaphysis and gradually spread to the diaphysis, but he admits that frequently it is very difficult to tell just where the primary focus was situated. Reichel divides surgical bone tuberculosis into primary joint or epiphyseal affections and primary tuberculous osteomyelitis affecting the diaphysis in circumscribed foci or in a diffuse manner involving the whole marrow canal and usually leading to partial sequestration. Caan prefers Küttner's classification with modifications as follows:

I. (A) Primary shaft tuberculosis. This may be secondary to some other tuberculous focus not in the bones, central and peripheral lesions.

(B) Primary in the metaphysis and from there spreading to the shaft.

II. Primary in the joint or epiphysis and from there spreading to the shaft. Of this class of lesion, there are several types:

a. Progressive infiltrating tuberculosis.

b. Caries carnosa.

c. Type similar to the previous two forms but characterized by a chronic course and better prognosis.

Schinz describes an osteosclerotic form of bone tuberculosis affecting the shaft. This is a rarefying osteitis, spread out in multiple foci over the shaft, not involving the joints, to which is added a coincident ossifying periostitis. The spongy cortex, he says, cannot be differentiated from the spongy periosteal stratification. He also describes a rare form with no circumscribed foci but characterized by a diffuse, progressive and specific granulation tissue formation without any tendency to caseation. The affected bones are greatly rarefied, periosteal changes are weakly defined or are entirely lacking in the roentgenogram and endosteal reaction is evidenced only to a mild degree by a spotty appearance. In sections, the bones seem to be destroyed. This destructive type is evidently the caries carnosa of other writers. Brown and Stiefel call this the granulating or fungous type, occurring rarely, most often seen as a sequel to shoulder joint tuberculosis and known as caries carnosa, because non-caseating red granulation tissue containing few tubercles is seen, extending the entire length of the bone, destroying it from inside out until the cortex remains only as a thin shell.

Sorrel and Sorrel-Déjerine describe three phases in the production of the hypertrophic lesion of the shaft as seen in the roentgenogram: (1) periosteal proliferation resulting in the formation of a shell surrounding the shaft; (2) isolation of a sequestrum in the interior of the shell, and (3) fragmentation of the sequestrum and destruction of the periosteal shell. These phases correspond to three clinical stages: (1) tumefaction without abscess formation; (2) collection of an abscess; (3) formation of fistulas.

Friedländer described three types of shaft lesions: (1) solitary metaphyseal focus, identical with an epiphyseal focus on the other side of the epiphyseal line; (2) the infiltrative focus from the medullary cavity; (3) the periosteal focus.

Allison in reporting his study of 50 cases of bone tuberculosis states that the usual

terms of classification which are employed are: (1) the encysted lesion; (2) the infiltrating lesion; (3) the atrophic lesion, and (4) the hypertrophic lesion. Furthermore he states that it has been the usual policy to classify separately the joint lesions and regard them as distinct entities: (1) acute miliary synovitis; (2) chronic tuberculous synovitis; (3) granulating or fungating synovitis, and (4) fibrous tuberculous synovitis. In these instances, he believes the observer has described one phase of tissue reaction and has regarded it as a clinical entity. He thinks a simpler classification should be used. Tuberculous infection that gains a foothold in any certain region such as cancellous or cortical bone, the metaphysis, the epiphysis, the bone marrow, the joint capsule, the ligaments and synovial membranes, behaves in a manner corresponding to the structure involved. There is no reason pathologically or clinically to consider these lesions from the standpoint of contrasted bone or joint involvement.

Allison believes that the disease is primarily a disease of bone. He is not sure in what tissue the primary infection takes place but he is certain that in all of his cases the bone became the chief seat of the infection. In regard to the lesions situated in the shaft away from the epiphysis, he says the process is characterized by a marked tendency to bone proliferation, but although it might be regarded as hypertrophic in type, in all of his cases which showed these characteristics, areas of destruction were also found. Thus when the infection invades areas that readily produce new bone as a reaction to infection, then destruction predominates. In all his cases when compact bone was involved, proliferation predominated; when cancellous bone was affected, the lesion proved to be destructive. The pathologic process is to be regarded as not essentially different in its manifestations wherever it may occur. Thus observers cannot properly describe one phase of tissue reaction such as fungating or granulating, etc., and consider it a pathological and clinical entity.

Allison and Fisher (1916) were able to produce tuberculosis experimentally in any portion of the long bones of dogs. They found that when the focus was implanted under the periosteum or in the diaphysis, a proliferative process resulting in the formation of new bone occurred. When the epiphysis or the joint surface was inoculated, this reaction did not occur. This observation seemed to confirm that of Fraser (1912) who described hypertrophic shaft lesions.

Jüngling (1920) described a cystic condition of the metacarpals, metatarsals and phalanges, associated with lupus vulgaris, in the hands and feet of young adults. Occasionally the cuneiform, cuboid, ulna, and nasal bones were affected. He could obtain no definite proof but considered the syndrome was tuberculous in etiology and suggested the name "osteitis tuberculosa multiplex cystica." In 1928, Jüngling collected reports of 46 cases to which he added 9 of his own. Schwentker has lately (1931) reported the first case of cystic tuberculosis of bone occurring in an infant. In his case, cystic areas were formed in the diaphysis as well as in the epiphysis. He explains that in the former, the lesion usually developing in tuberculosis of bone is modified by periosteal reaction. There is central caseation with surrounding fibrosis, but the entire lesion is limited by the formation of new bone in the subperiosteal region, so that the process is apt to assume a piriform or spindle-shaped outline. The caseous process may predominate with subsequent formation of abscesses and sinuses. If fibrosis is more pronounced than caseation, a cystic lesion may result, especially in the metaphyso-epiphyseal areas which may remain unchanged for long periods or may progress to the formation of abscesses or may retrogress to almost complete healing.

Greig (1932) has lately explained the pathological changes of shaft tuberculosis on the basis of the theory of bone formation as formulated by Leriche and Policard. Greig's theory seems to summarize the ideas of this later school so thoroughly that

his description is quoted in detail. Leriche and Policard treated bone as connective tissue. Osteoblasts are fibroblasts, enlarged on account of their activity and their only claim to osteoblastic power is that by their death they may, and probably do, facilitate the transference of calcium from the colloidal condition in which it exists in the blood serum and lymph to the condition in which it is present in bone. Or the death of these cells may liberate some constituent which affects the metabolic activity of other cells or modifies the local circulation. Osteoblasts are nothing more than mere foreign body cells which help to absorb dead bone by halisteresis or to remove it as granules to the best of their poor ability, and this they do, Greig states, far less efficiently than does the serous effusion in which a sequestrum is bathed.

Every trauma, Greig thinks, brings about a liberation of histamine which provokes a local reaction, a dilatation of capillaries, a local hyperemia, a local dedifferentiation, a readjustment and a redifferentiation. The redifferentiation occurs as the hyperemia recedes and a new trabecula forms as the old one thickens on the side that is at rest, and gradually the whole bone changes its shape and architecture. Periosteum, like bone, is a connective tissue and a derivative from the mesoblast. It differs from the ordinary fibrous connective tissue in the degree of its vascularity. It has two functions, that of a limited membrane and that of a pathway for the blood and lymph vessels and for the nerves to the bone which it ensheaths.

Shaft tuberculosis changes the diaphysis from its normal shape to a thin-walled fusiform expansion. The process of this change, according to Greig, is not generally appreciated. Tubercles do not distend the bone from pressure within, inasmuch as this is impossible, bone being a rigid structure. The presence of tubercles, their bacilli and their toxins, within the marrow cavity, or within the haversian canals, or even on the surface, acts as a foreign body and as such provokes a histamine-induced hyperemia. When the hyperemia reaches a certain degree, a consequent decalcification follows with the proliferation of fibroblasts. The bone thus becomes soft and the softened tube now reaccommodates itself to its contents and

Figs. 7 and 8. Same case as shown in Figure 6 five years later. Complete healing of the tuberculous focus in the shaft and the epiphysis. The infection has now spread to the knee joint, affecting especially the articular surfaces of the femur and tibia, outer half, and the entire patella. In the meantime the patient had a fracture of the femur at the junction of the middle and lower thirds which has firmly united and which accounts for the periosteal and cortical thickening in this area.

with this relief hyperemia diminishes and at once the local excess of calcium is utilized to form new bone. The hyperemia varies in intensity and coincidently decalcification and recalcification alternate, yet proceeding synchronously, throughout the affected part of the bone, and the gradual readjustment which takes place is greater at its middle than at the extremities of the affected portion, and so continues until, in some cases, the whole shaft participates. The sheath of the new bone is formed at the periosteum because there

FIG. 9. Tuberculous osteomyelitis. Same case as shown in Figure 5. Opposite forearm. The radius and ulna show marked periosteal and cortical change. In the radius the process involves almost the entire shaft.

and there only, in the diseased bone can be the necessary combinations of adequate blood supply and the excess of calcium salts. Subperiosteal formation does not mean that the formation is periosteal in origin.

COMMENT

The roentgenographic appearance of the lesion in the fibula of the case reported here shows no characteristics comparable to any of the various types of lesions previously described. A search of the literature revealed only one type of lesion which resembles the appearance of this case. Caan in describing tuberculous lesions solely affecting the diaphysis, describes the central and peripheral types. The former begins in the cortex, is usually of the caseating variety in which the granulation tissue becomes quickly caseous before it absorbs the surrounding bone tissue. When the caseating tissue shuts off the circulation, sequestration occurs. Further sequestration results from the fact that the original sequestrum lies in a cavity lined with tuberculous granulation tissue and so healing does not occur. Further, in the diaphysis

FIGS. 10 and 11. Marked expansion of the periosteum with thickening of the cortex of the tibia in a child three years of age. Blood Wassermann of both the patient and his mother, positive. Syphilitic dactylitis at the age of six months. When compared with Figures 3 and 4 the difficulty of differential diagnosis from the productive type of tuberculous lesion is obvious.

the caseating lesion is modified by periosteal reaction, there being central caseation with surrounding fibrosis. The entire lesion is limited by the formation of new bone in the subperiosteal region so that the process is apt to assume a spindle-shaped or a piriform outline.

Caan's second type is a peripheral lesion which this case seems to resemble. This is a rarer type than the former. Foci are small and have a superficial situation, either periosteal or subperiosteal or superficial in the cortex. They often lie close to the skin and their size can be easily estimated by palpation of the overlying soft part swelling. According to Krause, it occurs mostly in children or in young persons who show other old or recent tuberculous foci and the bones usually affected are the humerus, ulna and tibia. It is sometimes a manifestation of multiple tuberculosis of bone. It may occur also in persons of any age who have shown no previous evidence of tuberculosis in any part of the body, but who in a comparatively short time develop multiple foci in other organs, bones, joints, skin, lymphatic glands, etc.

The lesion in the fibula in our case was definitely superficial. A tumefaction was present. An additional focus soon developed in the humerus. No other tuberculous foci were found on the first examination. In many respects, this case is similar to the description of Caan's second type.

DIFFERENTIAL DIAGNOSIS

The difficulty of differential diagnosis need scarcely be mentioned inasmuch as it is so extremely obvious. The dense, fusiform or spindle-shaped swelling of the middle of the shaft in the hypertrophic type cannot be differentiated from the similar type of lesion produced by syphilis in the same area. This difficulty has been fully discussed by Lovett and Wolbach. The destructive lesion, here reported, presents the same difficulty in differentiation from syphilis and could also be mistaken for a malignant lesion.

ROENTGENOLOGICAL TYPES OF DIAPHYSEAL LESIONS

The various roentgenological types of diaphyseal lesions which have been encountered by us, for comparison with the cases reported, are as follows:

I. Lesions confined strictly to the diaphysis:

1. The destructive superficial type (Figs. 1 and 2).

2. The periosteal or productive type, much more frequent (Figs. 3 and 4).

II. Lesions involving the diaphysis, the metaphysis and often the epiphysis.

1. The productive, periosteal type (Fig. 5).

2. The type of lesion presenting a large, sharply defined area of rarefaction involving the metaphysis and extending across into the epiphysis (Figs. 6, 7 and 8).

3. Tuberculous osteomyelitis involving the major portion of the entire long bone or very often the entire bone (Fig. 9). Case reports of these lesions are of frequent occurrence in the literature and the lesions are often more extensive than the case here shown.

SUMMARY

A case of a destructive tuberculous lesion in the shaft of the fibula is reported. Other diaphyseal and metaphyseal lesions are reproduced for comparison. Tuberculosis of the shaft has long been recognized, but because of its rather infrequent occurrence has been little described in American roentgenological literature. It must be considered as a possible cause of an obscure shaft lesion, especially when multiple foci are found elsewhere.

We wish to express our appreciation and thanks to Dr. J. H. Underwood for his permission to report this case.

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DISCUSSION

Dr. L. T. LeWald New York City. I have seen two cases proved to be tuberculosis of the shaft of the radius. I wanted to ask Dr. Bromer if there was a possibility of the bovine type of tubercle bacillus being responsible for these shaft lesions rather than the human type, because there are a great many more cases reported abroad, particularly in England, of tuberculosis of the shaft of the bones, where it is a well-known fact that control of bovine tuberculosis is not as well carried out as it is in this country. I think Dr. Bromer's contribution is a very important one.

Dr. Ross Golden, New York City. I had the occasion to see the first case shown by Dr. Bromer before he did, and I called it an osteogenic sarcoma. This patient had a large swelling over the fibula which at first was stony hard and later became soft and rather fluctuant, suggesting fluid. Over that lesion there was a little periosteal reaction which didn't show very well on Dr. Bromer's slide. I was very much surprised, needless to say, when I heard that tuberculosis had been found in this lesion. I had the opportunity in England four years ago to see a sclerosing lesion of the lower end of the radius about an inch above the joint with a lace-work periostitis which we have been taught is characteristic of syphilis. I have seen exactly the same thing, to me indistinguishable, in a case of osteogenic sarcoma and in another case of nonspecific osteomyelitis. Dr. Twining, of Manchester, who showed me this film, kindly sent me a print of it later and a report of the operative findings which proved it to be tuberculous.

I wish to express my appreciation to Dr. Bromer for taking up this interesting subject as it seems that we are meeting this problem more and more frequently. In the last two years I have had occasion to see two other cases and the differential diagnosis to me is extremely difficult.

Dr. A. B. Gill, Philadelphia. In these cases of tuberculosis of the shaft of long bones which Dr. Bromer has shown there are, I think, two types. There is the rare type in which the primary lesion is in the shaft or diaphysis and it remains confined to this location and may be of the unusual sclerosing form. In the other type the primary lesion is in the metaphysis near the end of the bone, but the disease has spread thence into the diaphysis. Tuberculosis of bone originates commonly in the epiphysis or the metaphysis and comparatively rarely extends into the shaft. But there is a fulminating type of bone tuberculosis with rapid growth of the disease and involvement of the medulla just as there is a fulminating type of pulmonary tuberculosis which years ago was called "galloping consumption."

Whether or not new bone formation ever occurs in tuberculosis has been doubted or denied by some orthopedic surgeons. But it has been observed occasionally. I think it is more apt to occur in these cases of shaft tuberculosis than in tuberculosis of cancellous bone because osteogenesis of subperiosteal bone is more marked in the shaft than in the ends of long bones. But not all disease of the shaft leads to sclerosis. A punched-out appearance of the shaft is sometimes seen which is difficult of diagnosis. New bone formation has also been observed in vertebral tuberculosis.

Dr. Bromer (*closing*). In answer to Dr. LeWald's question, Fraser and Stiles in Edinburgh have written a great deal on this subject. I, unfortunately, cannot be absolutely definite in my answer. I am not certain whether they have proved that the prevalence of this type of tuberculous shaft lesion is due to the greater occurrence of bovine tuberculous infection in man than infection with the human strain.

In the hurry of presenting this paper I did not emphasize the point that Dr. Gill brought out, that the majority of cases presented by us are not cases of true shaft tuberculosis. Two only were shown. The one case, that of Dr. Downs', is the peripheral, or the superficial cortical or subperiosteal or periosteal type of lesion described by Cohn in his two types of primary shaft tuberculosis. The second case is an example of the sclerosing type which is more frequently found than the peripheral lesion. Küttner drew hard and fast lines and insisted lesions of the metaphysis should not be included in shaft lesions. He also excluded secondary lesions arising from foci in the epiphysis. Cases of this latter sort were reported by us in order to make the study complete and cover all types of shaft tuberculosis.

The question of the rôle the periosteum plays in the formation of the sclerosing type is interesting. Is it entirely a limiting membrane with no bone-producing functions or does it assist in the sclerosing process and new bone formation? This question has not as yet been definitely answered.

ACTINOMYCOSIS OF THE SPINE*

By J. L. TABB, M.D., *and* J. T. TUCKER, M.D.
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ACTINOMYCOSIS is widely distributed in this country, being especially prevalent in the upper Mississippi Valley and in the Northwest portion of the United States. It is far more common than one is led to believe from the scattered cases occasionally encountered in this locality. Nearly every region in the body has been known to be affected, but the spine is one of the rarest sites known, and it is for this reason that this particular case is of interest.

BIOLOGICAL

Le Blanc is given the credit of being the first to write of this disease known then as "lumpy jaw," described so vividly from the picture that cattle so infected gave. It was not until 1877 that Bollinger and Hartz described the organism that caused this condition so readily recognized in cattle. One year later Israel and Wolff isolated the same organism from humans.

Actinomyces or ray-fungus is normally saprophytic, growing upon grains, grasses, and similar vegetable matter. In order that this infection may be established, some of this vegetable matter must be introduced into the tissues. As a consequence, the infection is commonest about the mouth.

Conn at the Agricultural Experiment Station, Geneva, N.Y., found that the total floral and sod soil contained 38 per cent *Actinomyces* while the cultivated soil contained only 20 per cent. To account for this, anaerobic conditions were thought to greatly favor the growth but aerating the soil produced no effect. It was then observed that this fungous growth lives best on decaying roots of vegetables and plants. Microscopically the characteristic, radiating, clubbed ends of the mycelial filaments give it the name of ray-fungus. The exudate from the infected tissues contains the characteristic granules, small, yellowish particles, commonly known as sulphur granules, which can be distinguished with the naked eye.

ORIGIN AND MODE OF INFECTION

The first manifestation of the disease is usually found about the jaw or in the tongue; in either of these localities there is produced considerable enlargement which is dense and fibrous, called wooden tongue or lumpy jaw. It is generally considered that man and beast obtain their infection from a common source. Any individual who is careless about chewing straws, twigs, grasses or grain, or who is neglectful in the care of his mouth and teeth, may thus be readily infected. Moos reports two cases of infection traced to chewing strap. Hummel reports one case of *Actinomyces* abscess of the tonsil pierced by an oat chaff.

The following questionnaire was prepared and sent to each of the 40 cases which were treated at the Mayo Clinic:

1. Have you ever in any way come in contact with horses or cattle affected with lumpy jaw or any disease simulating it, such as old ulcers, or swellings about the animal's head or neck?
2. Have you been in the habit of chewing on straws or blades of grass or picking your teeth with same?
3. To what extent have you eaten of fresh uncooked vegetables such as lettuce or celery?
4. Have you at any time had decayed teeth or other tooth troubles?
5. State as accurately as you can what has been the cause of the disease and what treatment you have carried out.

As a result of these questionnaires, 57 per cent reported animal to man infection; 40 per cent admitted fondness for chewing straws, grasses, grains, etc.

Skin infections are thought to be due to direct contact. Pulmonary infections may be explained by two modes of invasion: one

* Read before the Richmond Academy of Medicine, May 24, 1932.

through catarrhal infections, analogous to bronchitis, such as inhaling chaff of grain, the other through a destructive disease of the pulmonary parenchyma itself. If the pleura once becomes involved, there is rapid spread by continuity to the chest wall.

For those interested in the general subject of actinomycosis we refer them to the excellent article by Mattson.[2] This writer covers the biological characteristics, origin and mode of infection, portals of entry, pathological features, clinical course, differential diagnosis and treatment, together with several case reports.

FREQUENCY

Ruhrah, in 1899, published a review of 1,094 cases. None of these, however, were localized in the vertebrae. Inich sometime later reported 421 cases. The sites of distribution were as follows: head and neck, 56 per cent; pulmonary, 15 per cent; digestive tract, 20 per cent; skin, 2 per cent; doubtful, 6 per cent.

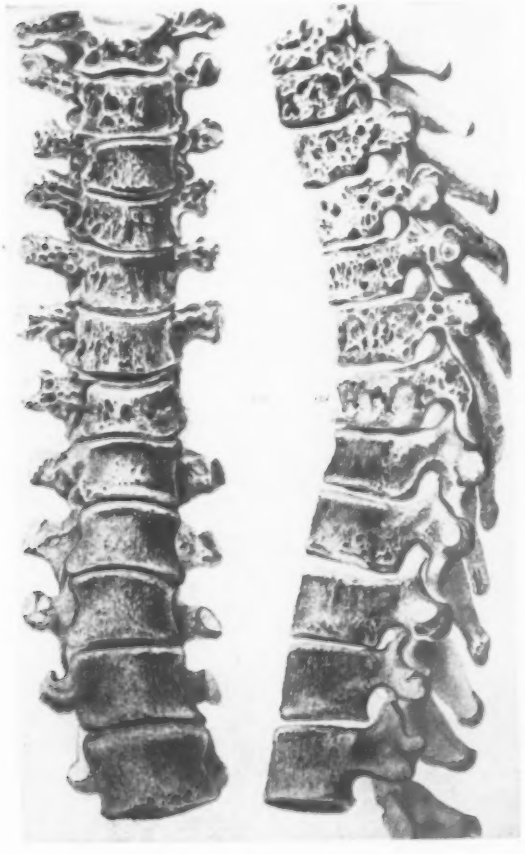

Fig. 1. Bostom's case of actinomycosis of spine. (Reprinted with permission from the *Journal of Bone and Joint Surgery*, 1923, 5, 759–777.)

Fig. 2. Roentgenogram of specimen of actinomycosis of spine. (Parker's[3] case. Reprinted with permission from the *Journal of Bone and Joint Surgery*.)

Sanford, in 1923, reported 678 cases which were either acute or chronic and localized in every part of the body.

Parker[3] in 1923 reported 8 cases of vertebral involvement, which seems to be a complete review of the literature up to that date.

Ward[6] reported a case of skin, lung and spine infection. He suspected actinomycosis but the case was at first incorrectly diagnosed as tuberculosis at the hospital to which the patient was sent. Later, however, the mistake was corrected after an examination of the pus.

FIG. 3. Roentgenogram of specimen of blastomycosis of spine. Part of destruction due to portion resected for study. (Parker's[3] case. Reprinted with permission from the *Journal of Bone and Joint Surgery*.)

Simpson and McIntosh[4] cover the subject of spinal actinomycosis very thoroughly. The literature was reviewed and 28 cases were found. To these they added 4 cases of spinal infection from their own experience. These four cases were diagnosed clinically as tuberculosis of the spine. They believe that much information may be gained from roentgen studies, and their views are in accord with others that actinomycosis does not show the same predilection for the vertebral bodies as does Pott's disease.

CASE REPORT

CASE 1. White male, aged thirty-three, dentist by profession, was referred to us by Dr. Joseph L. Wright of Harrisonburg with a letter stating that the patient had had a small actinomycotic infection of the neck.

Family history essentially negative.

Past history negative except actinomycotic infection of the skin on the left side of the neck with operation October 1, 1931, which resulted in a general breakdown October 14, 1931.

Present Illness. Has had pain in left hip and in sacroiliac region and down sciatic nerve almost to the left knee. He first noticed this following the operation for actinomycosis on the left side of the neck. He was operated on as follows: first incision, October 1, then incision and curettage of area fourteen days later, October 14.

He awakened one morning, October 15, and found that the right arm was numb but paid no attention to this and shortly thereafter noticed that the left arm was becoming numb. He massaged his arms and then noticed that the whole body became numb. On getting up, he could move but did not have control of his body. He was helped back in bed where he had severe pain over heart lasting about ten minutes. He stayed in bed about three weeks following this attack. On getting up, he was conscious of pain in the left side of back; back

FIG. 4. Case 1. Note large perivertebral abscess outlined by arrows.

hurt after bending or sitting, especially when straightening up. There was soreness in left hip. He had never had a roentgen examination. In April, 1931, patient states that he had pain in right sacroiliac joint but pain disappeared and nothing was done about it. He has had several severe colds since August 1. No history of chewing grain, straws, grasses or the like.

Physical Examination. White male, 5 ft. 11½ in. tall, underweight for height, pale and apparently anemic. Neurological signs negative. Mouth healthy. Teeth in excellent condition. Linear scar under left jaw bone well healed.

Examination of Back: Patient stands with trunk tilted slightly to the right. Some limitation of motion in spine on bending backward or to either side. Pain over lumbosacral joint on forward or backward bending. Rotation of the lumbar spine limited, with discomfort. Leg raising negative. Both thighs forcibly flexed on abdomen discomforting. Extension of spine with thighs painful in lumbar region. Pain over skin area about site of left 11th osteocartilaginous junction. Referred for roentgen examination of spine.

Laboratory Examination. Urine essentially negative. Blood: red cells, 4,460,000; white cells, 9,600; hemoglobin, 75 per cent; color index, 0.7; polymorphonuclears, 81 per cent; lymphocytes, 18 per cent; eosinophiles, 1 per cent. Smears from larynx and nose, negative; smear of sputum showed ray-fungus present; no acid fast bacilli found.

Fig. 5. Case 1. View of dorsal spine showing the perivertebral abscess.

Fig. 6. Case 1. Notice the sharply defined areas of destruction in the bodies of the 10th and 11th dorsal vertebrae.

Roentgen Report. *Spine:* There is a sharply defined area of bone destruction in the body of the 11th dorsal, which extends downward from the disc between the 10th and 11th almost through the body. A similar sharply defined area of bone destruction is seen involving the lower portion of the body of the 10th dorsal. The intervertebral space shows some narrowing. Large paraspinal abscess pockets are seen on each side of the spine in this region. In spite of the rather large area of destruction in the vertebral bodies there is no tendency to collapse and patient complains of very little pain in this region.

Chest: Heart, aorta and diaphragm appear normal. The shadows of the abscess pockets described above are seen showing through the heart shadow.

FIG. 7. Case 1. There is no collapse of the vertebral bodies and only slight narrowing of the intervertebral space.

Right Lung: Nothing of clinical significance is noted.

Left Lung: There is very marked bronchial thickening and the upper lobe presents small scattered areas of infiltration.

The left side of the mandible shows no bone lesion.

Summary. This patient has definitely proved actinomycosis involving the soft tissues of the left side of the neck.

The examination of the sputum reveals the characteristic organism of actinomycosis with no evidence of the tubercle bacillus. The multiple, sharply defined areas in the 10th and 11th dorsal segments, the early abscess formation with very little pain in this region, and the absence of any tendency towards collapse of the vertebral bodies are more in accord with the diagnosis of actinomycosis than with Pott's disease.

Conclusion. Patient has actinomycosis of the soft tissues of the left side of the neck, the upper half of the left lung, and of the 10th and 11th dorsal vertebrae.

While there are detailed descriptions of the roentgen findings in actinomycosis of the lungs, the roentgenological descriptions of actinomycosis of the spine are rather scarce. This is to be expected in view of the very few cases that have been recognized. George and Leonard in their excellent book "The Vertebrae," *Annals of Roentgenology*, 1929, vol. VIII, fail even to mention the condition. Baetjer and Waters in their book "Injuries and Diseases of the Bones and Joints," 1921, have only three lines devoted to actinomycosis and these refer chiefly to the jaw, namely, "Actinomycosis usually affects the jaw and produces a chronic osteomyelitis, with no special characteristics which make a differential diagnosis possible by x-ray." Christie's "Roentgen Diagnosis and Therapy" contains nothing on this subject.

Holmes and Ruggles have more to say concerning spinal actinomycosis. In their volume "Roentgen Interpretation" (fourth edition) the following is found: "Chronic lesions such as those of actinomycosis or blastomycosis produce irregular areas of destruction, usually in several bodies which, however, do not collapse. Chronic peri-

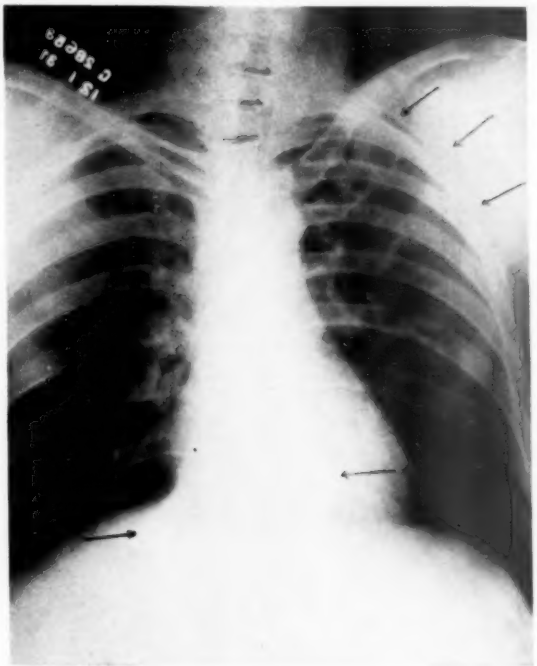

FIG. 8. Case 1. Actinomycosis of the left lung. There is lung infiltration in the periphery of the upper left lobe which is roughly outlined by the arrows. The lower two arrows outline the perispinal abscess which is visible on the film but not in the reproduction.

vertebral abscesses accompany these lesions and the responsible organism may be isolated in the discharge from their sinuses."

Parker[3] who thoroughly reviewed the literature with reference to spinal actinomycosis and blastomycosis up to 1923 writes under a roentgenogram of actinomycosis: "X-ray of specimen showing the peculiar patchy appearance of the affected areas in all the bodies and pedicles without collapse of the bodies, an x-ray appearance unknown in tuberculosis." In the same article he mentions that the spinous processes, transverse processes, laminae and adjacent heads of the ribs have been found at autopsy to be involved. In the section on blastomycosis he gives a beautiful roentgenographic illustration with extension to both ribs. There is only slight collapse of the vertebrae.

Both of the roentgenograms referred to were made of specimens procured at autopsy and of course could not show the perivertebral abscesses which were present in each case. In his review of previous cases Parker has not encountered sequestration except in the form of detached spongy material. He finds that, "A marked destruction of the vertebral bodies may take place before a collapse of their substance occurs." With reference to blastomycosis, Potter is quoted in this same article as follows: "The primary constant finding in the active lesion in bone is that of a localized dissolution. So intense and well defined is this process that it results in the peculiar condition in which centers of completely dissolved bone lie immediately adjacent to spongy bone tissue entirely intact."

We have covered *The American Journal of Roentgenology* from the beginning of its publication to the present time and although we have found some few articles on actinomycosis they deal mostly with infection in the lungs and other organs and with the therapeutic value of the roentgen ray. The same may be said with reference to *Radiology*.

Snoke[5] reports 5 cases of actinomycosis with 4 autopsies. In one case a perivertebral abscess was found at autopsy. He does not mention a roentgen examination of the spine in this case and gives no description of the vertebral bodies.

Jones and Alden[1] report 6 cases which occurred in Georgia. In one case roentgen examination revealed involvement of the sternum and skull. These writers believe that actinomycosis is more prevalent than we suspect and hold that "the finding of the sulphur granule is not necessary for a diagnosis." They believe that these granules occur mostly in long-standing cases, and for an early diagnosis a search for the fungus should be made from the scrapings of the sinus wall.

The descriptions of previous writers and the findings in this case lead us to believe that we may describe the roentgen findings in actinomycosis of the spine as follows:

1. This disease usually attacks two or more vertebrae. It produces rarefied areas which are very sharply defined, and apparently normal bone texture may lie adjacent to and between these rarefied areas.

2. It involves the bodies, pedicles, laminae, and the different processes of the vertebrae, also the ribs adjacent thereto apparently without any predilection for the bodies, which contrasts strongly with tuberculosis where the vertebral body bears the brunt of the attack.

3. The intervertebral spaces show little if any narrowing, and a marked destruction of the vertebral body or bodies may take place without any collapse or kyphosis. The opposite is usually the case in tuberculosis.

4. Large perivertebral abscesses form rather early and are a constant finding. The organism can be found where a sinus has formed.

5. Sequestration has not been encountered.

6. There is usually lung infection where the spine is involved. Roentgen examination of the lungs will show the involvement and the organism may be detected in the sputum.

The case reported has definitely proved actinomycosis of the skin. The sputum which was examined by a competent pathologist failed to show the tubercle bacillus but showed the ray-fungus. There are now fluctuating masses under the skin of the back but no sinus has as yet formed and in justice to the patient aspiration has not been done for fear of secondary infection. We do not feel justified in possibly hastening a draining sinus for purely scientific reasons. When the sinus forms an examination of the pus will be made for the ray-fungus, but in view of the clinical and roentgen findings we believe that the spinal condition is most probably that of actinomycosis. There is one feature that is of interest: although this patient has localized vertebral destruction and large perispinal abscesses the pain is not severe. He walks with a normal gait, is active and is able to travel without any material discomfort. It has been our experience that a patient with Pott's disease with abscess formation is usually in severe pain and unable to get about, so much so that he will welcome any means of fixation to the spine.

TREATMENT

Mattson[2] reports heroic doses of potassium iodide given in lung and appendicial cases, as a specific; initial doses of 75 drops of saturated solution three times a day; increase drop daily until 125–150 drops three times a day are given. Surgery is valuable when the part involved is of an operable nature. Wide excision and curettage have been reported successful. Local injections of phenol in strong solutions, or even application of crystals, is advocated by some with favorable result.

Roentgen rays and radium have been used in conjunction with potassium iodide therapy but with little noticeable effect, as all the cases so extensively involved came to a fatal termination. Vaccines have been advocated but none are available.

Where there is pain about the peripheral nerves, and involvement of the spine to any extent, mechanical support is indicated.

Our patient is being given 125 drops of saturated solution of potassium iodide three times a day by mouth. He also receives an intravenous injection of potassium iodide once daily. A modified Taylor back brace is being worn and he is undergoing a series of deep roentgen therapy to the spine. A recent communication tells us that there seems to be some improvement.

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Vol. XXIX, No. 5

IVORY VERTEBRA

By H. C. OCHSNER, M.D.,* *and* R. H. MOSER, M.D.
INDIANAPOLIS, INDIANA

VERTEBRE d'ivoire is the name given by Souques, Lafourcade and Terris[7] to the roentgenographic syndrome of increase in density of an isolated vertebral body with retention of the normal size and contour, and with no changes in the intervertebral disc. Nové-Josserand, Contamin and Rendu,[6] and Vincent and Giroire[8] subsequently designated the condition "vertèbre noire" due to the fact that the positive roentgen image is black. Other observers have preferred the term "vertèbre opaque." This syndrome represents a symptom rather than a disease entity. Nevertheless, the findings are sufficiently definite to warrant a discussion of the condition.

Condensing osteitis may occur in a variety of diseases. Foremost among the causes of a localized condensing osteitis are metastasis from a malignant process, lymphogranulomatosis, and Paget's osteitis deformans. A majority of the reported cases of ivory vertebra represent instances of osteoplastic metastasis, especially from the breast and prostate. The existence of a primary malignant disease from which metastasis might occur can usually be determined by careful clinical examination. The vertebral involvement in lymphogranulomatosis may be osteoplastic, although osteoclastic changes usually predominate.

Bársony and Schulhof,[1] whose review of ivory vertebra is the most comprehensive in the literature, believe that many cases represent a local manifestation of Paget's disease. Hallermann[3] has described his observations in 70 cases of Paget's disease, in 90 per cent of which the lesion was confined to the spine alone. The most frequent changes were a thickening of the peripheral and a thinning of the central portions of the bodies of the vertebrae. In a few instances there was a fine porous atrophy of the entire vertebral bodies. He emphasizes the importance of a mosaic-like structure; in his illustrations the condition resembles primary hemangioma more than ivory vertebra. It would seem, therefore, that the findings in a majority of the cases of Paget's disease are unlike those of "ivory vertebra." Hultén[4] has described a case of Hodgkin's disease in which the characteristic findings of ivory vertebra were noted in the second lumbar vertebra.

Breitländer[2] described a central sarcoma of the body of the fifth lumbar vertebra which produced a homogeneous increase in the density of the body of the vertebra without alteration in form. This condition is extremely rare, but can be excluded by observation of the course of the disease.

Localized increase in density of a vertebral body may occur in myelogenous leucemia, in which event the blood changes would suggest the true diagnosis. In the osteosclerotic anemia of old age there is a scattered increase in density of the bones. In tuberculous spondylitis the concomitant roentgenographic changes such as involvement of the disc and paravertebral abscess are usually helpful diagnostic criteria. A negative serology and failure of response to antiluetic therapy assist in the elimination of lues, which is usually associated with changes in the outline of the affected vertebra.

Although a condition similar to ivory vertebra may develop as a sequel to typhoid fever, Keith and Keith[5] state that the characteristic changes produced in the spine are destructive, with involvement of the intervertebral discs, which are thinned and blurred. The first changes are in the disc, followed by an involvement of the body, with the formation of exostoses and of bony deposits in the adjacent lateral ligaments.

Diffuse osteosclerosis, osteopoikilosis, or marble bones, is never restricted to an individual vertebra. In these conditions, too,

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there may be anemia, enlargement of the liver and spleen, and nervous manifestations. The melorheostosis of Léri is a flowing hyperostosis of a single extremity, and does not involve the vertebrae.

Fig. 1. Cervical spine, illustrating opacity of the sixth cervical vertebra.

Bársony and Schulhof suggest that the sclerosis of ivory vertebra may represent a reaction to a bacterial embolism with bacteria of low virulence. A local chronic infection might thereby be set up, and eburnation result just as it does about the roots of chronically infected teeth, or in Garre's sclerosing non-suppurative osteomyelitis.

In the case which we wish to report, there are changes in the pelvis suggestive of early Paget's disease. Changes typical of ivory vertebra were found in a single vertebral body, with little evidence of expansion. There was pain out of proportion to the roentgenologically demonstrable changes in the spine.

When first seen in March, the patient, a woman aged seventy-five, suffered acute pain in the left forearm and the three lateral digits. The pain was so severe that she often walked the floor until exhausted. The left hand was constantly held in the right, because of an extreme hyperesthesia of the hand. There had been no noticeable change in the color or in the temperature of the affected extremity. There had been no pain in the right arm or in either lower extremity. The onset of these symptoms was in January, 1931; there had been a rapid increase in intensity until the time of the first examination in March, 1931.

The temperature was normal; the pulse 100. The blood pressure was 190 systolic and 100 diastolic. There was a moderate enlargement of

Fig. 2. Pelvis, showing osteitis, particularly marked in the left ilium.

the heart, and an occasional extrasystole was present. Moderate arteriosclerosis was found in the peripheral and retinal vessels. No enlargement of the superficial glands was detected. General reflexia was normal. The tonsils were not grossly abnormal, and roentgen examination of the teeth was negative. Examination of the abdomen, pelvis, and rectum disclosed nothing of note.

The left arm, forearm, and hand showed no atrophy; all muscle groups were intact, and reflexes were normal. The fingers were normal in color, and were held in a semi-flexed position. There was an extreme hyperesthesia of the distal phalanges of the three lateral digits. The lower extremities were very edematous to the knee.

The urine contained a moderate amount of albumin. The initial blood count was hemoglobin 80 per cent (Sahli); erythrocytes, 4,500,000; leucocytes, 25,100, with 90 per cent

polymorphonuclear neutrophiles and 10 per cent small lymphocytes. Blood calcium was 9.8 mg. per hundred, and non-protein nitrogen 32 mg. The blood Wassermann reaction was negative.

During a period of observation the pain became progressively more severe, and the patient was hospitalized from April 2 to April 15, 1931. During that time her temperature was normal except on the ninth day, when it rose to 100.8° F. Urinalysis was negative except for the occasional presence of a few leucocytes. There was a moderate anemia; the hemoglobin ranged from 70 to 80 per cent by the Sahli method, and the erythrocyte count from 3.4 million to 4.5 million. There was a constant elevation of the leucocyte count, which varied from 15,600 at the time of admission to 12,250 when the patient was dismissed. Supravital staining revealed none of the characteristics of lymphatic leucemia, although the stained smear showed from 38 to 59 per cent lymphocytes.

Roentgen examination of the left elbow and of the chest revealed no evidence of a pathologic process. Films of the spine revealed a generalized hypertrophic lipping of the articular margins of the bodies of the vertebrae. There was a complete opacity of the body of the sixth cervical vertebra (Fig. 1) without alteration in its size or shape, and without interference with the integrity of the intervertebral discs. Films of the pelvis (Fig. 2) demonstrated a fibrous osteitis of the sacrum and of the lower margin of the left ilium, extending to the acetabulum. Roentgen therapy was administered on April 7 and 8, 1931. A suberythema dose was given through a lateral portal on each side of the involved segment of the spine. The treatment factors were 170 kv. peak; focal-skin distance, 12 inches; filter 0.25 mm. Cu and 1 mm. Al; 70 ma-min. Following these treatments the patient was somewhat relieved, but some pain persisted. She was again treated on May 20 and 21, using the same factors, and complete and permanent relief resulted. At present—August, 1932—the patient is in excellent health, and has no pain whatsoever. There has been no change in the roentgen appearance of the pelvis, but the density of the sixth cervical vertebra is somewhat less marked.

This case is reported because of the comparative rarity of the condition, the difficulty of accurate differential diagnosis, the marked subjective neurologic findings, and the prompt and lasting response of the condition in this patient to roentgen therapy.

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TRICHOBEZOAR*

By H. DABNEY KERR, M.D., *and* EDWIN L. RYPINS, M.D.
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BEZOARS, as a group, have been known since the twelfth century B.C. The term bezoar has been applied to masses found in the stomach and intestines of both men and animals. "They were highly prized and sought after as remedies against poisons and pestilential diseases" (Balfour and Good[1]). This superstition regarding their medicinal effects has persisted until recent times as the bezoars of the buffalo, when sectioned and placed over a dog bite, were supposed to prevent hydrophobia.

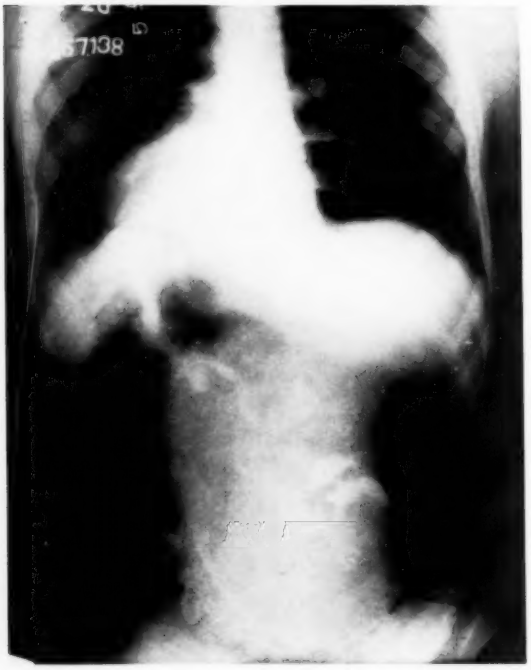

FIG. 1. Anteroposterior view with patient standing. Note how the mass is almost completely outlined by the barium.

INCIDENCE

The first case of trichobezoar or hair-ball, as it is commonly known, was reported by Baudamant in the *Journal de Médecine, Paris*, in 1779.[7] The first one to be reported as having been removed at operation was that of Schoenboin in 1883.[7] Trichobezoars are particularly common in the cow, the horse, and the rat, especially during the hair-shedding seasons.[6] According to Balfour and Good, hair-ball is the most common of all types of bezoar. Up to 1930, 139 cases of bezoar had been reported and 20 of these were phytobezoars or food-balls, thus leaving 119 cases of trichobezoar (Camp[3]). LeWald also believes trichobezoar to be common, yet it is interesting to note that Butterworth[2] in 1909, was able to collect only 42 cases, thus indicating that with the more frequent use of the roentgen ray more cases are being reported.

ETIOLOGY

"Most of the cases are in females of the English speaking races" (Maes[6]). This is in accordance with the views of Butterworth who adds that, "very few trichobezoars are found reported in the German literature."

The condition is uncommon in males, as Maes in 1928 was able to find only 2 cases which had occurred in this sex.

Butterworth, Matas, and Maes, all agree that the habit of young girls wearing long hair predisposes them to biting the hair. The condition is analogous to that of biting the finger nails. Butterworth further states, "In seventy-five percent of the collected cases, the patients were known to have acquired the habit during childhood."

The mentality of the patients is normal, since demented patients usually eat more solid substances, such as nails (Butterworth; Matas). Maes, however, believes that there is a psychic factor as in a case which had a trichobezoar removed, the patient began eating hair during convalescence, and he and LeWald[9] each cite a case in which during a period of years the pa-

* From the Department of Roentgenology, State University of Iowa, Iowa City, Iowa. Presented before the University Hospital Medical Society, January 19, 1932.

tient was operated on five times and a trichobezoar removed each time.

The hair making up the trichobezoar is usually the patient's own hair, although Matas cites the case of a woman, a brush-maker, who ate the bristles used in making the brushes.

DIAGNOSIS

The diagnosis of trichobezoar is usually made by the roentgen ray. As Balfour and Good remark, "With a barium meal, the stream divides or pours over an object in the antral part of the stomach. The shadow of the object looks like an empty space or an air bubble" (see Fig. 1). This same view is held by Maes[6] and Porter,[5] while Köhler[3] adds, "In screening, during the taking of the contrast meal, one can see how, on entering the stomach, the barium appears to divide at once into two parts, which flow together again below."

The six-hour film is of special importance (see Fig. 2), as Holmes and Ruggles[4] state,

Fig. 2. Posteroanterior view six hours after the barium meal with patient in the horizontal position. Although stomach is empty, the mass is still outlined by adherent flecks of barium.

Fig. 3. Photograph of trichobezoar.

"The barium mixture adheres to them [hair-balls], thus outlining their structure, and they are visible for some time after the meal has left the stomach."

CASE REPORT

J. L., male, white, aged twenty, admitted to the surgical service of University Hospital December 21, 1931. Family and past history not essential. Present symptoms date from about June, 1929, at which time patient was thrown from a horse and horse was supposed to have stepped on patient. Symptoms consist of a dull pain in epigastrium, not related to meals, and a mass in the epigastrium. Patient was often nauseated but did not vomit.

Physical examination revealed a non-tender mass in the epigastrium. Mass was firm and moved with respiration, and on standing the mass would move 8 cm. to the left and downwards. Mass was about 10 cm. long and 6 cm. wide (see Fig. 3).

Blood examination, including the Wassermann, was negative. Gastric analysis showed a rather low acidity but this can be explained by the fact that the duodenal tube merely rested on the mass (Fig. 1) and never reached the pars media.

Differential Diagnosis. A retroperitoneal hematoma, a pancreatic cyst, a tuberculous peritonitis with a rolled up omentum being the mass, malignant lymphoma of the stomach, and a foreign body in the stomach were considered in the diagnosis. The patient showed no evidence of tuberculosis in the chest and had no anemia. With a malignancy of the size the mass appeared to be, we should expect more or less cachexia. The patient was well nourished. We were confident, from our roentgenoscopic examination, that the mass was in the stomach. Thus extragastric conditions could be excluded. The patient was asked if he had eaten persimmons lately, but he stated that he did not know what persimmons were. However, a roentgenologic diagnosis of phytobezoar was made.

Patient was operated on December 26, 1931, by Dr. H. L. Beye, with a preoperative diagnosis of a new growth of the stomach, possibly malignant, and a trichobezoar was removed which weighed one pound (see Fig. 3). At operation the gastric mucosa appeared hypertrophied. Microscopic examination of the section of gastric mucosa merely showed chronic inflammation.

Patient made an uneventful recovery and a gastric examination at time of discharge showed the stomach to be about normal in size.

Psychiatric examination was negative. Patient had normal mentality.

DISCUSSION

The unusual features of this case were that the patient was a male, and only two previous cases have been reported in males (Maes). Also this trichobezoar looked like horse's hair, being very black. The patient's hair was light in color. However Matas says, "When dry, the hair-ball gave the appearance of the fur of a wild animal." This patient firmly denied having eaten hair, which is not in accord with the report of Butterworth, who stated that if accused, the patient usually admitted the practice. The hypertrophy of the gastric mucosa has been noted also by Matas.

SUMMARY

1. Trichobezoars can be diagnosed roentgenologically as they give a characteristic appearance, especially after six hours, following the administration of barium mixture by mouth (see Fig. 2).

2. This case is of interest as nearly all cases of trichobezoar previously reported have been in the female sex.

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Vol. XXIX, No. 5

CHRONIC RADIUM POISONING IN RATS*

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I. INTRODUCTION AND LITERATURE

FOR many years the soluble salts of radioactive substances have been used internally in the treatment of certain diseases. These salts have been most frequently administered through injection of the salts in physiological saline solution or by mouth in drinking water. Less often, inhalation of air containing radioactive gases has been used.

A large number of authors have reported remarkable improvement in a wide variety of diseases.

Newcomet (1914) reported that radium taken in drinking water lessened the glycosuria in diabetes mellitus and that it was valuable in the treatment of primary and secondary anemias, leucemias, and various types of arthritis.

Delano (1915) reported some work of Cameron and Proescher in which they had given 1,800 injections of radium salts over a period of two years without observing any harmful effects. Quantities up to one milligram had been given to some patients. He concluded that the emanations of radium were a tonic and a stimulant, increasing the number of red blood cells and hemoglobin in the blood and improving or curing pernicious anemia. Several authors have reported radium valuable in the relief of pain in arthritis and other conditions (Moriarta, 1918; Sterns, 1920; Mittenzwey, 1921).

It apparently never occurred to these workers that some of the radium might remain fixed in the body for many years and cause serious damage later. In fact, it was not until 1924 that a dentist (Blum) who was treating some of the luminous watch dial painters, suspected radium as the cause of an occupational disease. This discovery led to investigations which soon established radium within the body as definitely injurious.

Nine girls who had previously been luminous watch dial painters died from 1922 to 1924 (Martland, 1929). One of the bodies was exhumed five years later and found to be radioactive.

In the skeleton of one of the girls who died was found 150 micrograms of radioactive material. The largest amount of activity was in the bones, liver, and lungs.

In a recent paper Martland (1931) reported the development, in several of the dial painters still living, of radiation osteitis, osteogenic sarcomata, and anemias.

The Bureau of Public Health reported (May, 1931) an investigation of 242 employees in seven watch and clock manufacturing industries. Examination of the bones showed focal atrophy and focal sclerosis in 19 per cent of the workers who had pointed brushes in their mouths (those employed before 1926) and in 1.3 per cent of those employed since 1926 (when pointing

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of brushes with lips was supposed to have ceased). The focal atrophy was more severe in those persons with more than one microgram of radium in their bodies.

Interest in the rate of elimination of radium has been considerable since the early

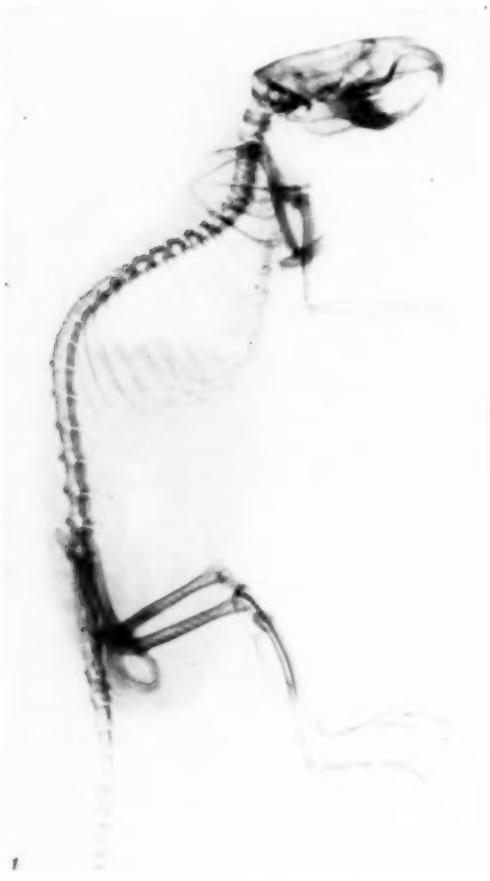


FIG. 1. Rat No. 9 (female control). Roentgenogram taken 166 days after the beginning of injections of radium in the experimental rats.

days of the use of radium as an internal therapeutic agent.

In 1915, Seil, Viol, and Gordon reported that during the first three or four days the elimination of radium taken by mouth was about twice as rapid as if given intravenously. In the former case 25 to 30 per cent of the radium remained after four or five days and in the latter case 55 to 60 per cent remained. After five days the elimination was at about the same rate in both cases. After the tenth day less than 1 per cent per day was eliminated.

Recently Barker and Schlundt (1930) made tests on patients who had been treated internally with radium for several years. The radium was estimated in these patients by adding the values obtained from measurement of the expired air for radon and from measurement of the body by the gamma-ray method. These investigators found that all patients who had ceased taking radium two years or more before the tests had completely eliminated it although one of these patients had been given 380 micrograms over a period of two years. Another patient gave a negative test seven months after cessation of a course of treatment in which 80 micrograms had been given intravenously.

Schlundt (Schlundt and Failla, 1931), experimenting on himself, found that in the first four days he eliminated 91 per cent of a dose or radium bromide taken in drinking water and at another time he eliminated 98 per cent of the radium in five days.

Schlundt and Failla (1931) determined the rate of excretion of radium from two girls who had become radioactive twelve years before. They found that one of the girls had 24 micrograms of radium element in her system and eliminated 1,161 micromicrograms or 0.005 per cent of the total per day. The other girl, whose total activity was 14 micrograms, eliminated 363 micromicrograms per day or 0.0026 per cent of the whole.

It is thus seen that there is considerable variation in the excretory rates of different individuals. At the present rate it will take the first girl about two and one-half years and the second about five years to eliminate one microgram of radium.

There have been several attempts made to increase the rate of elimination of the radium which has become fixed in the bones.

Collip produced a parathyroid extract which caused hypercalcemia in dogs (Collip, Clark, and Scott, 1925), and Hunter and Aub (1927) found that this extract also

increased the rate of elimination of lead and calcium from the bones.

In 1926 Flinn (Flinn and Seidlin, 1929) used four injections of ammonium chloride and parathyroid extract on a radium poisoning case and found that the stools increased in radioactivity. Of 3 patients treated for seven weeks with Collip's parathyroid extract, one showed a 45.6 per cent decrease in activity, another a 57.7 per cent decrease, and a third a 50.5 per cent decrease.

This same author (Flinn, 1931) found that following the administration of viosterol to patients with radium poisoning there was a great increase in the activity of the expired air. An attempt is being made to increase the rate of radium elimination by alternating periods of treatment with parathyroid extract and viosterol. The former causes a rapid elimination of calcium and phosphorus from the bones, and the viosterol aids in the deposition of new calcium in the bones.

II. MATERIALS AND METHODS

This experiment has been carried on with the view of producing a chronic radium poisoning by the action of small amounts of radium over a long period of time rather than an acute effect by the use of large doses of radium.

Ten albino rats were chosen for the experimental animals. Five of these were females and were all litter mates. The other five were males and were all litter mates. When the rats were procured, the females were sixty-seven days old and the males sixty-five days old. One male and one female were chosen at random to be used as controls and the other four of each group were used for injections.

The rats were all placed on a good growth producing diet and kept on this diet throughout the rest of their lives. An excess of food was kept before the rats at all times. Each rat was kept in a separate cage. These were round cages with a bottom of wide meshed wire netting which allowed all excreta to pass through it. The cages were placed on large pieces of absorbent paper which in turn lay on glass plates. All the solid excreta remained on top of the paper. The fluid was absorbed by the paper and practically all the residue from the urine remained in the paper after drying. This was proved by the fact that washings of the glass plates showed negligible amounts

Fig. 2. Rat No. 10 (male control). Roentgenogram taken 195 days after the beginning of injections in the experimental rats.

of radioactivity. At the desired intervals these papers were changed. Each paper, together with the excreta, was ignited at about 600°C., the residue placed in a small test tube (5 c.c. capacity), stoppered, sealed with paraffin and kept for later quantitative radium determination.

The rats were weighed as soon as procured and at frequent intervals thereafter. Rats No. 1, 2, 3, and 4, were the experi-

mental females, and No. 9 the female control. Nos. 5, 6, 7, and 8 were the experimental males, and No. 10 the male control. The weights of the females ranged from 100 to 120 grams and those of the males from 154 to 173 grams.

Two weeks after the animals were procured, injections were begun. Each dose was contained in a sealed glass vial and consisted of 5 micrograms of radium chloride* in 2 c.c. of physiological saline solution. Injections were given at irregular intervals, the total doses in the various rats ranging from 40 to 60 micrograms, and the elapsed time between the first and the last injection ranging from 117 to 191 days. All of the injections were made subcutaneously either in the lower part of the abdomen or in the medial part of the thigh.

TABLE I
DETAILS OF RADIUM TREATMENT

No. of Rat	Amt. of Radium	1st Inj. to Last Inj.	1st Inj. to Death	Age at Death
	μgm.	days	days	days
1	40	126	187	267
2	60	191	258	338
3	50	134	209	289
4	55	134	200	280
5	60	134	183	261
6	50	134	194	272
7	40	117	186	264
8	60	191	200	278
9	—	—	—	338
10	—	—	—	283

Table 1 shows the amount of radium injected into each rat, the elapsed time between the first and last injection, the time from the first injection till the death of the rat, and the age of the rat at death.

Blood counts were taken on rats No. 1 and 8. The first counts were taken before the first injections and others were taken at intervals throughout the rest of the lives of the rats. Counts were made on other rats at times when it was desired to determine the degree of anemia or condition of the blood forming organs. In each case the blood count consisted of a total red cell count, a total white cell count, and a differential white cell count. The blood counts were taken primarily to keep a check on the degree of poisoning rather than to find the immediate effect of the radium injections on the blood picture.

Roentgenograms were taken of some of the rats to determine the effect of the radium on the bone density and structure.

The rats were closely observed throughout the course of the experiment for any signs of abnormal changes in the condition of the body and the general activity, and for any lesions noticeable from the exterior.

Attempts were made to mate some of the rats to determine whether or not they had become sterile.

As soon as possible after a rat had died, the body was examined for gross changes, and various tissues were taken for histological examination.

Rat No. 5 was used entirely for determining the radium content of various parts and of the whole body.

Rat No. 1 died at full term of pregnancy. The fetuses were removed and the radium content of the mother and the fetuses were determined separately.

In most of the other rats, the tissue not taken for histological study was used for radium content determination. In several cases various bones were radiographed by exposing photographic plates to the rays emitted from the radium in the bones.

III. BLOOD CHANGES

Since it was desired to follow only the general trend of the blood picture, counts were taken several days after the injections rather than closely following them.

All the rats showed a progressively developing anemia. The decrease in red cells was slow at first, but became more rapid before death.

The normal blood picture for this group of rats was: red blood cells, 10,000,000 per cubic millimeter; white blood cells, 12,000

* The standardized radium solutions for this work were furnished by the United States Radium Corporation, through its Vice-President, Howard H. Barker.

to 18,000 per cubic millimeter; and lymphocytes, 60 to 80 per cent.

The blood of rat No. 7 contained 3,808,000 red blood cells and 4,608 white blood cells per cubic millimeter on the day before its death.

The most striking picture of anemia was that of the blood of rat No. 2 in which the red cell count decreased from 6,280,000 to 2,112,000 during the two weeks preceding its death. During the first week of this two-week period the white cell count decreased from 12,000 to 7,000, but on the day of death of this animal it had reached 18,800. This great rise was probably due to a severe infection as it was preceded by an increase in neutrophil percentage.

The differential white counts showed a gradual increase in lymphocyte percentage,

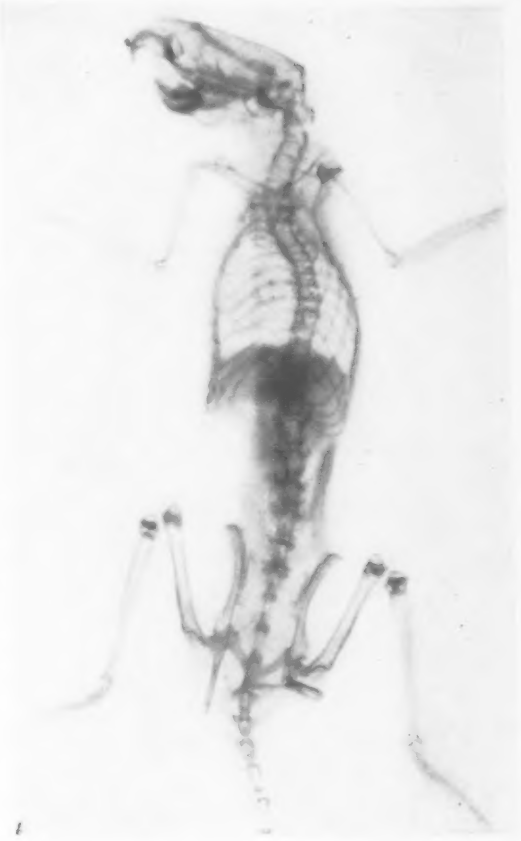


Fig. 4. Rat No. 8. Roentgenogram taken 195 days after the beginning of injections. Sixty micrograms of radium chloride had been given.

reading 96 and 98 per cent in two cases, followed by a slow fall. There was a great increase in lymphoblasts in the circulating blood paralleling the rise in lymphocyte percentage. Some of the lymphoblasts were binucleated. Hyperlobulated polymorphonuclear neutrophils and myelocytes were present in some cases.

The blood cells themselves showed the changes of a secondary anemia. Polychromatophilia, anisocytosis with microcytes, poikilocytosis, hypochromemia, and spherical shaped red blood cells were constant findings. Macrocytes and normoblasts were found in a few cases.

Fig. 3. Rat No. 5. Roentgenogram taken 166 days after the beginning of injections. Forty micrograms of radium chloride had been given.

IV. WEIGHT CHANGES

The rats all grew rapidly and about doubled their weights during the first fifty

days of the experiment. Following this gain the injected rats all remained at a fairly constant weight for two or three months and then lost rapidly till at the time of their deaths they had returned to about their weights at the beginning of the experiment.

FIG. 5. Rat No. 2. Roentgenogram taken 239 days after the beginning of injections. Sixty micrograms of radium chloride had been given.

The controls continued to gain long after the others had ceased and their weights remained at a high level till after all the other rats had died.

V. GROSS PATHOLOGICAL CHANGES OBSERVED DURING LIFE

For several weeks after the beginning of injections the rats showed no grossly visible abnormal changes. In time, however, the injected rats began to fail to gain weight as rapidly as the controls and later began to lose weight. They showed a loss of activity and before death became very lethargic. Their fur lost its fine texture and they failed to keep themselves clean. The eyes became progressively paler.

Pathological fractures due simply to muscle pull on the weakened bones occurred in at least three rats (Fig. 3). In two rats a femur was heard to snap during the struggle at the time of injection. The direct etiology of two other fractures (Figs. 3 and 4) is not known but the rats were never in a position in which they were subjected to trauma.

A few days before its death, rat No. 6 developed a motor disturbance in its hind legs.

VI. BREEDING EXPERIMENTS

Attempts were made to breed four of the injected rats.

Rat No. 5 was placed with four normal female rats and left with them for three days. This rat died sixteen days later. No pregnancies occurred in any of the females.

Rat No. 6 was placed with three females for two days and died two days after removal. No pregnancies resulted in any of these females.

Rat No. 1 was placed in a cage with a normal male for four days. Twenty-one days after being taken away from the male this rat died and at autopsy eight apparently normal full term fetuses and one 6 mm. fetus were found in the uterus.

Rat No. 4 was placed with a male for four days. This rat died thirty-four days later and on opening the abdomen the uterus was found to contain seven or eight nodular swellings, each measuring about 6 $\times$8 mm. Histologically these nodules were composed of necrotic tissue. They represent fetuses which had partially developed, died, and were in the process of resorption at the time of the death of the rat.

VII. BONE CHANGES AS SHOWN IN ROENTGENOGRAMS

In each case an injected rat and a control rat were etherized together and placed side by side on the same roentgen film and at the same distance from the roentgen tube.

All of the injected rats showed approximately the same bone changes except for considerable quantitative variations (Figs. 1 to 5).

The upper incisor teeth were more curved than normal and showed an increased density. The lower incisors were shorter than normal and failed to meet the upper ones by several millimeters in most cases. The skulls showed areas of decreased density. All the large bones contained areas of increased density in those parts immediately adjacent to the joints. These changes were especially marked around the knee joint and at the ends of the vertebrae. There was a concentration of calcified bone around the crests of the ilii and the ischial tuberosities in some cases.

In three or four of the rats there were irregular nodular enlargements at the costochondral junctions (Fig. 5). The central portions of the vertebral bodies showed a very noticeable decalcification and the shafts of all the long bones showed a marked thinning of the compact bone.

The skeletons of the injected rats were smaller than the control skeletons and there was a great decrease in the soft tissues.

VIII. GROSS PATHOLOGICAL CONDITIONS OBSERVED POST MORTEM

All the injected rats had extensive abscesses in the soft tissues around the mandible but in only one case had drainage to the exterior been established.

Rat No. 2 and the female control, No. 9, were killed at the same time and so a good comparison between the pathological and normal was possible. The liver, lungs, kidneys, and spleen were of a very much lighter color in the injected rat. The spleen was about six times normal size. There were uneven nodular enlargements at all the costochondral junctions of rat No. 2 (Fig. 5). These consisted of a soft, chalky or caseous material which allowed the ribs and costal cartilages to be pulled apart with very slight force.

The uterine horns of rat No. 4 contained seven or eight nodular enlargements, each measuring about 6×8 mm.

The left lung of rat No. 6 contained a large amount of purulent exudate. There were subpleural petechial and ecchymotic hemorrhages in the lungs of several of the rats.

In all the injected rats the bones were much more easily broken than in the controls. There was a thinning of the compact bone shown by the fact that the bone mar-

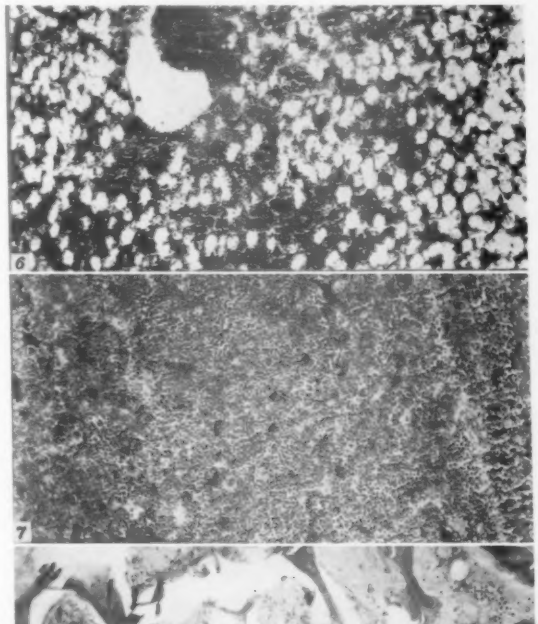


Fig. 6. Section of the bone marrow of the shaft of the femur of rat No. 10 (×120). This is typical normal bone marrow as found in all parts of the skeletons of the controls.

Fig. 7. Section of the bone marrow of rat No. 4 (×120). This is a typical picture of aplastic bone marrow as found to a greater or lesser degree in the vertebrae, sterna, mandibles, ilii, and in the extremities of the long bones of all the injected rats.

Fig. 8. Section of the shaft of the femur of rat No. 6 (×120). This is the typical hyperplastic marrow as found in the central two-thirds of the shafts of all the long bones of the injected rats.

row could be easily seen through the bones in many places. The dorsum of the skulls of the rats was cut through for removal of the brain. These were found to be much harder and thicker in the controls than in the injected rats.

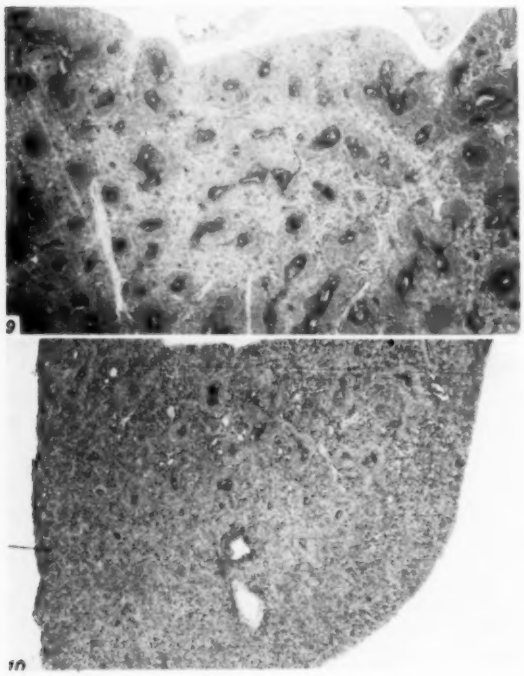


Fig. 9. Section of the spleen of rat No. 10 (male control) ×20. This is a normal spleen and shows the Malpighian corpuscles very distinctly.

Fig. 10. Section of the spleen of rat No. 6 (×20). This is a typical picture of the spleens of all the injected rats. The Malpighian corpuscles are practically indistinguishable and the whole section has a more homogeneous appearance than normal.

IX. HISTOPATHOLOGY

By far the most important histological changes were found in the hematopoietic organs, namely, the bone marrow, the spleen, and the lymph nodes.

Bone Marrow. Stained sections made from the bones and bone marrow of the control rats showed the marrow spaces in all parts of the skeleton to be completely filled with marrow consisting of more or less solitary fat vacuoles surrounded by closely packed marrow cells. This arrangement of cells and vacuoles is shown in Figure 6 which is a section through the shaft of the femur of rat No. 10. In this marrow red blood cells were very numerous and tended to rouleaux formation. The white cells in order of their frequency of occurrence were polymorphonuclear neutrophils and eosinophils, lymphocytes, neutrophilic and eosinophilic myelocytes, and megacaryocytes.

In no part of the skeletons of the injected rats was this normal type of bone marrow found. However, all the injected rats showed the same type of marrow for any given part of the skeleton. In all cases, approximately the middle two-thirds of the shafts of the long bones contained a hyperplastic marrow in which the fat cells were completely replaced by the red marrow (Fig. 7). Also in all cases, an aplastic marrow was found in the extremities of all the long bones, in the vertebrae, the mandibles, and the ilii of the injected rats. In this aplastic marrow (Fig. 8) the cells had become greatly diminished in number or completely destroyed or removed from the marrow space and in their place was a thicker than normal fibrous network.

Intermediate stages between the aplastic and the hyperplastic marrow were found in the ends of the shafts of the long bones, and in the sternum of rat No. 4. In all the other sterna an aplastic type of marrow was present. In general, there was an increase in the myelocytic and decrease in the polymorphonuclear cell percentage in this abnormal bone marrow. Megacaryocytes were abundant in the hyperplastic marrow but very scarce in the aplastic marrow. Many of these cells were undergoing degenerative changes as pycnosis of the nuclei and disintegration of the cytoplasm.

Spleen. The spleens of the injected rats varied considerably but these variations were quantitative rather than qualitative. In size, they varied from slightly smaller than normal to about six times the normal size. All the spleens of the injected rats showed a gross loss of Malpighian corpuscles and microscopically a great diminution in the prominence of these struc-

tures. The stained sections had a homogeneous appearance as contrasted with the normal mottled appearance (Figs. 9 and 10). Normal lymphocytes were decreased in number and were scattered more or less uniformly throughout the spleens instead of being concentrated around the arterioles. Many lymphocytes were being ingested and destroyed by endothelial leucocytes and many showed degenerative changes as pycnosis and marginal concentration of chromatin. Immature lymphocytes were present in greater numbers than normally.

Cells normally found in the bone marrow but abnormal to the spleen were present in the spleens of all the injected rats. These cells were neutrophilic and eosinophilic myelocytes, and megacaryocytes, and were very numerous in some cases.

In the spleen of rat No. 3, eight or ten megacaryocytes were seen in every high power field. There was an increased number of endothelial leucocytes with ingested cells and blood pigment and in a few cases there was some fibrosis. In most cases red blood cells were present in very small numbers. All the spleens of the injected rats contained many plasma cells. Large cells were noticeably increased in number, and cytoplasm rather than caryoplasm had become the dominant substance.

Lymph Nodes. Lymph nodes from different rats or from different parts of the same rat varied considerably, but here again the variations were mostly quantitative. In all the nodes examined, there was a decrease in normal lymphocytes and an increase in immature lymphocytes. Plasma cells were numerous and endothelial leucocytes were increased in all cases. Myelocytes and megacaryocytes were present in varying numbers. In rat No. 4, a great many myelocytes were degenerating by the process of caryorrhexis and later pycnosis of the fragments of the broken up nuclei (Fig. 11). This process was also seen, but to a much lesser degree, in the lymph nodes of other rats.

Definite circumscribed germinal centers were absent. In many cases the whole lymph node resembled a large germinal center.

Submaxillary Glands. The mucous tubules of the submaxillary glands of three of the rats showed degenerative changes consisting of pycnosis of nuclei, marginal concentration of chromatin material, and a desquamation of the lining epithelium.

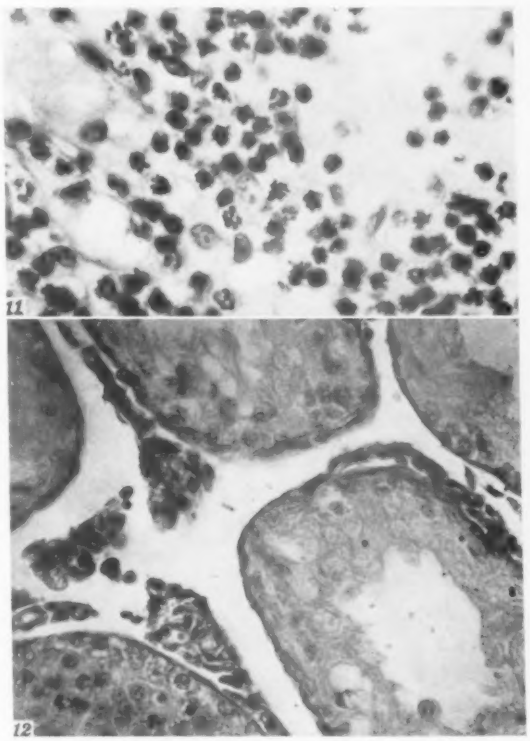


Fig. 11. Section of a lymph node of rat No. 4 (×1000). This picture shows the myelocytic cells degenerating by caryorrhexis and pycnosis of the fragments. Similar degenerating cells were seen in the bone marrow, spleen, and in the islands of myelocytic cells in the liver.

Fig. 12. Section of a testis of rat No. 7 (×525). This shows the extensive degeneration of some of the tubules of the testis.

Lungs. The lungs of all the rats contained areas of some type of lobular pneumonia, consisting of edema, hemorrhage, purulent exudate, or combinations of these. In two cases there was also a purulent bronchitis associated with a purulent exudate in the surrounding alveoli. Atelectasis and emphysema were present in some cases.

Liver. The most common change seen in this organ was a thinning of the trabeculae with the cells appearing compressed and staining darker and more homogeneously than normal.

In two cases numerous small islands of white blood cells were found scattered throughout the liver substance. Most of these islands contained lymphocytes but some contained myelocytes. They were located in the trabeculae and around the interlobular vessels.

Heart. In several cases there was a degeneration of the myocardium but no signs of inflammation were found. In a few cases there was some fibrosis and in one case there was a slight diffuse lymphocytic infiltration.

Kidneys. The most marked changes in these organs occurred in the convoluted tubules and the thick segments of the loops of Henle. These changes consisted of pycnosis of nuclei, disintegration of the cytoplasm of the lining epithelium, desquamation of epithelium, and in some cases a complete loss of all elements except the supporting network. Casts were present in some cases, and in all cases there were numerous small areas of calcification scattered throughout the whole kidney.

Suprarenal Glands. These glands from several of the rats contained many pycnotic nuclei in all the layers of the cortex and in the medulla. These were most prominent in the latter location where other signs of cellular degeneration were also noticed.

Thyroids and Parathyroids. In these glands of rats No. 2 and 3, which were the only ones examined histologically, no abnormalities were noticed.

Pancreas. No pathological conditions were noticeable either in the acini or in the islands of Langerhans.

Ovaries, Uterine Tubes, and Uterus. In the ovaries of all the rats there were some apparently normal follicles and corpora developing.

The ovaries of rat No. 4 contained large areas of necrotic tissue with many polymorphonuclear neutrophils surrounding them. The small portions of the uterine tubes adjacent to the ovaries were filled with a purulent exudate. The uterus of this same rat contained about eight nodular swellings each, measuring about 6×8 mm. microscopically, these masses consisting of tissue in a state of coagulation necrosis. They represent embryos being destroyed in utero.

Testes. A portion of a testis of rat No. 7 contained tubules in which there was nearly a complete absence of all germinal cells (Fig. 12). This was the most marked change found in any of the testes, but all of them showed some signs of degeneration of tubules and faulty sperm formation. All testes were still forming many apparently normal spermatozoa, however.

Bone. In the sternum of rat No. 4 there was a thick wall of fibrous tissue between the bone and the marrow. The periosteum was also greatly thickened.

In rat No. 6 the central area of the sternum had undergone complete necrosis and had been replaced by granulation tissue. Around this area there were masses of carious tissue and small islands of normal bone. Strands of fibrous tissue extended from the periosteum to the central granulation tissue and were growing in and replacing the necrotic tissue (Fig. 13).

The costochondral junction enlargements as seen in several of the rats consisted of a greatly thickened periosteum surrounding masses of necrotic tissue and carious bone, usually with some normal bone at the center (Fig. 14).

In many of the bones the trabecular network had been destroyed to some extent or had failed to develop normally. In most of the spaces where bone marrow had been destroyed there had also been an ingrowth of fibrous tissue.

X. THE RETENTION OF RADIUM

Since the discovery of radium poisoning, special interest has been centered upon the amounts of radium which become fixed in the bones and then follow an elimination process in the animal system similar to cal-

cium of which radium is a periodic homologue. Barker (1929), in discussing his results obtained from the analysis of postmortem specimens of bones and tissues from the body of one of the victims of radium poisoning contracted from the exposure to radioactive dust and emanations over a period of nearly ten years, mentions the possibility of the radium in an animal system following a course similar to that of calcium.

The eight experimental animals after their deaths were prepared for analysis by calcining the samples at a temperature of about 600°C., in an electric furnace of the muffle type, until nearly all the carbonaceous matter was burned off. The whole samples of ash were ground and intimately mixed so that the radium was uniformly distributed in the entire sample. The radium was determined in small portions of the composite by one or two of the standard methods (Schlundt, 1914, and Barker, 1918). In most of the determinations the analytical portions of the sample were first completely de-emanated by fusion with potassium bisulphate, or solution in nitric acid. After the lapse of a week or two the emanation which had accumulated in the sealed sample was separated quantitatively, collected, and transferred to the ionization chamber of a calibrated electroscope. From the observed increase in the drift of the charged leaf of the electroscope the small amount of radium present in the sample was then computed, and finally used to compute the total quantity of radium in the rat.

In measuring these small quantities of radium, special care was taken to avoid serious errors. One of the serious sources of error is the assumption that the portion of the sample taken for analysis is a fair appraisement of the entire sample. No result was considered reliable until duplicate or triplicate determinations checked. Blank tests of all reagents used were made, and large samples of bones from normal rats were tested for radium. These precautionary determinations gave values slightly above the natural drift of the charged leaf system, and when calculated gave values between 10^{-11} and 10^{-13} grams of radium in the large blank samples. These small corrections stand far below the radium content of the specimens analyzed.

Table II shows the results obtained on the eight experimental rats used. Values for retention percentage, found by dividing the quantity of radium retained by the quantity

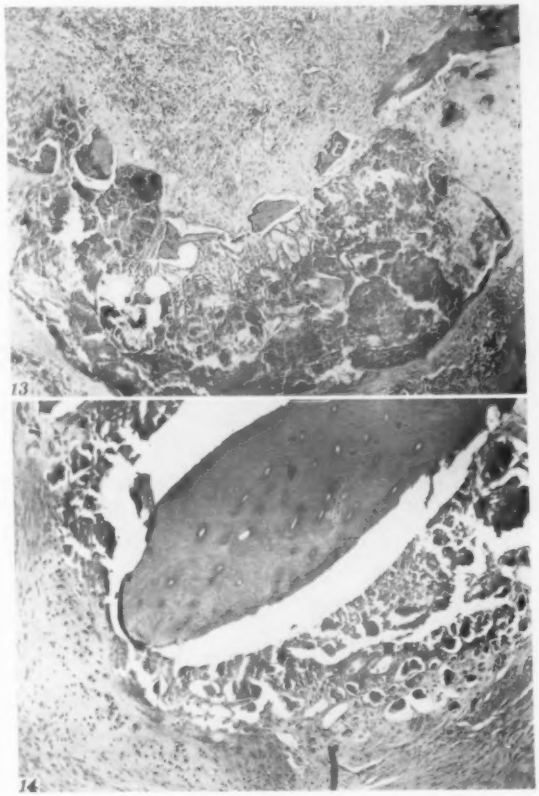


Fig. 13. Section of the sternum of rat No. 6 (×120). This photomicrograph shows the former marrow space filled with granulation tissue. Fibrous tissue is seen growing into the peripheral part of areas of necrotic tissue and carious bone. There are small islands of histologically normal bone completely surrounded by fibrous tissue.

Fig. 14. Section of a costochondral junction enlargement of rat No. 2 (×120). In this, caries of the base of the rib is seen progressing inward from the periphery. In the central part the bone is normal but just external to this normal bone is a rim of carious bone and still more peripherally is a thick mass of necrotic tissue with fibrous tissue growing into it from a greatly thickened periosteum.

injected, ranged from 15 per cent to 31 per cent; the average for the seven rats was 24.6 per cent. The usual length of life after the final injection was from sixty to seventy-five days, with slight dependence upon the length of time over which the injections were made, or upon the amount of radium injected. The first four rats were females and the latter four were males; the results fail to show any correlation between the sex of the rat and the retention percentage.

Not only was the retention percentage found for the full grown rats, but also in one instance the quantity of radium to be found in the fetuses of a radioactive female was determined. Rat No. 1, after having been injected with 40 micrograms of radium, was bred by a normal male. No subsequent injections were made, but unfortunately this animal died with the fetuses at full term. However, the fetuses were removed post mortem and subjected to similar treatment as the rest of the experimental rats. The results obtained from this experiment are shown in Table III. These results establish that the fetus of the radioactive female does receive radium from the parent. The relatively small concentration of radium in the ash of the fetus compared with that of the parent seems to point to the fact that there is but slight metabolism from the bone of the parent to the fetus.

TABLE II
RADIUM RETAINED AT DEATH
Post-Mortem Analysis

Rat No.	Period of Injection	Life Period After Final Injection	Radium Injected micrograms	Radium Retained micrograms	Retention Per Cent
1	126 days	61 days	40	12.4	31.0
2	191 days	67 days	60	17.1	28.5
3	134 days	75 days	50	11.6	22.2
4	134 days	66 days	55	8.6	15.7
5	134 days	49 days	60	15.4	25.8
6	134 days	60 days	50		
7	117 days	69 days	40	12.2	30.5
8	191 days	9 days	60	11.7	18.6

TABLE III
RADIUM RETENTION OF FETUSES OF A RADIOACTIVE FEMALE

	Concentration gm.Ra/gm. $\times 10^{-8}$ gm.	Weight of Sample, grams	Radium Retained $\times 10^{-8}$ gm.
Rat No. 1	106.21	11.6708	1239.6
Litter (eight fetuses)	3.80	0.5001	1.903
Per fetus			0.234
Radium in litter / Radium in mother			0.15%
Radium per fetus / Radium in mother			0.02%
Conc. Ra in ash of fetuses / Conc. Ra in ash of parent			3.58%

XI. THE DISTRIBUTION OF THE FIXED RADIUM

In order to determine the location and distribution of the radium in the system, two of the experimental animals, rats No. 3 and 5, were dissected and the various organs removed. The skeleton was also divided into sections to find out whether or not the bones from one part of the body had more radium than those from another part. The remainder of the soft tissue was termed the residue. The organs were not calcined, but instead, dehydrated in a vacuum desiccator. All the samples were subjected to similar treatment as the other samples mentioned previously. Rat No. 3, injected with 50 micrograms of radium over a pe-

riod of 134 days, died seventy-five days after the final injection. Rat No. 5, injected with 60 micrograms of radium over a period of 134 days, died forty-nine days after the final injection.

In both rats No. 3 and 5, the bones from the different sections of the bodies vary slightly in radium composition per gram. The mandible in both rats showed a lower composition, and proportionately lower in each animal. The relative higher concentration of radium in the bones of the hind quarters of rat No. 3 can be explained; these bones were calcined at higher temperature, 900°C. Therefore the ash was practically free from carbonaceous material and it is reasonable to believe that the sample was concentrated to a greater degree. Otherwise, if the bones from the different parts of the skeleton are compared the concentration of radium is practically uniform, differing only by 2 per cent.

TABLE IV

RADIUM CONTENT OF RATS NO. 3 AND 5

Portion	Quantity of Radium/gram $\times 10^{-8}$ gm.	Weight of Sample grams	Total Weight of Radium $\times 10^{-8}$ gm.	Per Cent of Total Radium
Rat No. 3				
Skull and vertebrae	156.52	3.9484	618.02	53.3
Mandibles	97.25	0.4407	42.85	3.7
Fore quarters	156.54	0.6566	102.78	8.8
Hind quarters	187.75	1.3449	262.84	22.6
Residue	69.92	1.9013	132.94	11.6
Total			1159.43	
Rat No. 5				
Intestines	1.025	1.5977	1.637	0.104
Spleen	0.342	0.1264	0.042	0.003
Heart	2.208	0.2342	0.523	0.034
Submaxillary gland	0.327	0.3859	0.126	0.008
Lungs	3.421	0.3564	1.219	0.079
Testes	0.268	0.4249	0.639	0.041
Liver	0.056	1.0922	0.052	0.004
Brain	0.547	0.7569	0.417	0.027
Kidney	5.142	0.4258	2.216	0.144
Skull and vertebrae	176.05	4.0008	704.33	45.6
Mandibles	114.64	0.5216	59.80	3.9
Fore quarters	176.38	1.7774	313.49	20.1
Hind quarters	178.87	2.5726	460.16	29.8
Residue	0.76	0.8939	0.69	0.1
Total			1544.657	

The results of the analysis of these two rats are given in Table IV. The weights of the samples of the organs are dry weight and the weights of the bone samples are calcined weight, therefore a comparison of weights between the two cannot be made. From the data on rat No. 5, it can be seen that higher than 99 per cent of the radium in the system was contained in the bones. For this reason the duplicate determination on rat No. 3 was only made upon the bone samples. The kidneys, lungs, heart, and intestines, follow the bones in activity in the order named. The other organs and soft tissue were slightly active but to a much smaller degree than the above mentioned samples.

Since it was found that the bones contained practically all of the retained radium, it was desirable to find if the distribution of the radium in each bone was uniform. Photography is the superior method

in the demonstration of the exact anatomical location of the radium. Although all the radioactive rays produce a photographic effect, in the ordinary ways of making radiographs the effect is produced by the beta and gamma rays and the alpha rays are completely stopped by the thin sheet of paper in which the plate is wrapped.

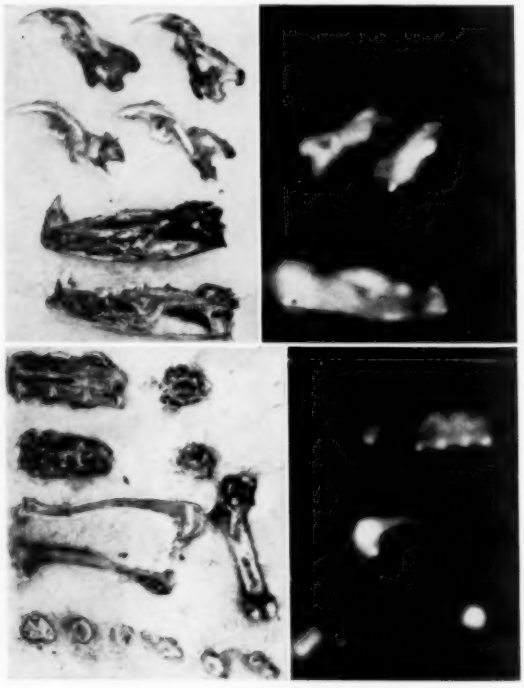


FIG. 15. Photographs (at left) and radiographs (at right) of bones from control and experimental animals. The controls do not register on the radiographs. Radiographs are placed as mirrored images of photographs.

At the outset of the experimenting, the clean, air-dry bones were mounted on a bed of cotton contained in a light proof box and a sheet of mica was interposed between the film (Eastman's "super-sensitive panchromatic" films were used) and the bones so as to guard against anomalous impressions which are sometimes obtained by mere pressure. The results obtained by this method showed an increased blurring as the times of exposure increased and that in all cases irregular fogging was caused by radon which continually emanates from the bone and diffuses through the cotton, depositing the active disintegration products in the cotton near the bone. The emanating power of the air-dry bones was found experimentally to be 35 per cent of the radon that was in equilibrium with the radium in the bone.

To overcome this fogging caused by the diffusion of the radon a method similar to the ingenious method used by Lacassagne, 1925, in his experimental work with polonium, was devised. The bones were dipped in hot paraffin which resulted in the formation of a coating of paraffin over the whole bone. By this procedure the radon was occluded within the bone as it was formed and forced to stay there to produce the active deposit at the place of formation. An additional coating of paraffin was added after the bones were mounted on the cotton prior to exposure of the film. The mica was discarded, and the film was placed directly over the bones. Duplicate bones from normal rats were placed with the radioactive bones in order to ascertain whether an impression would be caused by the pressure of the bone on the film.

Clean, air-dry bones from rat No. 7, containing 0.88 micrograms of radium per gram of bone, were cut so that longitudinal sections of the bones could be exposed to the film. In the case of the vertebrae a cross-section was also cut and this appears along side of the longitudinal section of those bones; the fibula was cut into cross-sections at various intervals along its length and these sections appear along the bottom of the photograph. Figure 15 shows a comparison between the actual photographs of the placement of the bones and the radiographs produced from a two weeks' exposure.

In all cases the paraffined specimens show a very much clearer image and a truer representation of the location of the radium in the bones. The paraffined specimens should be allowed to come to equilibrium after the dipping process because of the partial de-emanation of the bones in the hot parafin. It will be noted that bones

from normal rats similarly treated do not register on the plates.

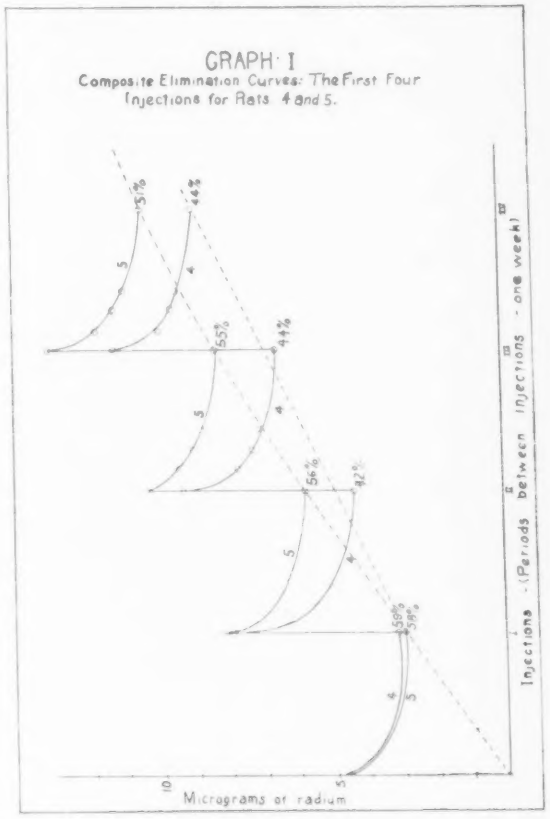
XII. THE ELIMINATION OF THE RADIUM

Most of the recent investigation of similar problems has been centered largely upon the elimination of radium from the animal system. Experiments performed to show the immediate elimination of radium after the reception have shown an extremely high rate of elimination. However, when the radium is administered orally, the immediate elimination is found to be higher than that for radium injected intravenously or subcutaneously.

The total excretion of each of the experimental rats was collected at varying intervals immediately after the start of the injections. These series of collections from the various rats were calcined at a temperature of 600°C., at which temperature all of the volatile organic material was dissipated. These small samples of calcined excreta were stored in small test tubes and sealed. After equilibrium had been fully established for all of the samples, gamma-ray determination of radium was made with the aid of a Wulf-Hess quartz fiber instrument (Hess, 1913 and Wulf, 1909). The very low natural drift of the instrument combined with a very high sensitivity, made this instrument very responsive to the comparatively weak activity of some of the samples. All the gamma-ray determinations were done in a laboratory especially reserved for such measurements and far removed from the radium laboratories.

However, in order to check the accuracy of results obtained by this method with results obtained by the emanation method which was used for the analysis of the rats themselves, eight samples from the eighty-two were chosen at random and their radium content was determined. The values obtained by the gamma-ray method of comparison checked within 2 per cent with values obtained by the emanation method. Hence, an accurate comparison can be made between excretion and retention of radium by the rats.

The results of these measurements showed a rapid elimination, approximately 35 per cent, for the first day following an injection, and a lessening for the remainder of the week, giving a value of 50 to 55 per cent elimination for the week after the injection. There was always a slightly higher percentage of elimination after each subsequent injection, explained by the fact that there is continually being retained in the animal system an amount of radium that has found its way into the bones and tissue, which is eliminated at a much slower rate than the radium that is merely being removed from the system without becoming partially fixed.


GRAPH I
Composite Elimination Curves: The First Four Injections for Rats 4 and 5.
Micrograms of radium
Injections - (Periods between Injections - one week)

This process of fixation of radium in the rats can best be shown by plotting curves for the elimination values of rats No. 4 and 5, for which more complete sets of data were obtained. Graph 1 shows these two sets of curves; since the excreta were taken

in weekly samples for the first two injections the curves for the elimination were assumed to take the general aspect of curves for the eliminations in other cases. The vertical lines represent the injections and the heavy curved lines show the quantity of radium retained in the system. The eliminations were measured for each rat for one week after each injection, and then the next injection took the curve 5 micrograms higher. The curves drop off very rapidly for the first day or two and gradually come to an approximately straight line of slight slope.

The dotted lines, drawn so that they show approximately the general trend of the retention values, show that the radium is accumulating in the system of the animal. However, a study of the percentages of retention at the end points of the individual weekly elimination curves shows that there is a slightly lower percentage of the total injected radium retained for the fourth injection than for the former ones. The conclusion from such results is that the excreta, after the first elimination, are made up of the abnormal elimination due to the excretion of radium that is not retained as fixed radium and the normal elimination due to the excretion of a certain small percentage of the radium that has previously become fixed.

Not only has the immediate elimination of the radium in the animal system been studied but also the normal elimination of the fixed radium. A few attempts have been made to increase the rate of elimination; Flinn and Seidlin (1929) reported that parathormone treatment, extending over periods of two to five months, produced an elimination amounting to 50 per cent of the radioactive material which had been held fixed in the system for five years or longer. Schlundt and Failla (1931) working on two victims of radium poisoning, contracted some twelve years prior to the experiment, found the average daily elimination of radium in the excreta for each. They divided this value by the total amount of radium in the patients and got values of 0.005 per cent and 0.0026 per cent respectively. These percentages were termed the coefficient of daily elimination.

We have computed elimination coefficients for two of the experimental rats. Excreta from rats No. 2 and 3 were collected several weeks after the final injection of radium. For rat No. 2 four weekly collections were obtained before death, but for rat No. 3, only two weekly collections were obtained before death. Rat No. 3 did not die a natural death but died while being subjected to ether. These samples were ashed and the radium content determined by the emanation method, the activity being too low for accurate gamma-ray comparison.

The results for the analysis of the weekly excreta are given in Table v. The weekly elimination in the case of rat No. 2 was much less in the two weeks just prior to

TABLE V

NORMAL ELIMINATION SEVERAL WEEKS AFTER THE FINAL INJECTIONS AND A FEW WEEKS PRIOR TO DEATH

Rat No. 2	Total Radium Eliminated $\times 10^{-9}$ gm.
4th week before death	10.05
3rd week before death	11.21
2nd week before death	4.44
1st week before death	2.92
Total for four weeks	28.62
Average weekly elimination	7.15
Amount retained at death	1711.60
Coefficient of weekly elimination	0.42%
Average weekly elimination for only 3rd and 4th week before death	10.63
Amount retained at death	1711.60
Coefficient of weekly elimination	0.61%
Rat No. 3	
2nd week before death	8.26
1st week before death	6.11
Total for two weeks	14.37
Average weekly elimination	7.18
Amount retained at death	1159.43
Coefficient of weekly elimination	0.62%

death which were also the periods when lessened activity and eating were noted. It seems that these values would not be accurate values to be used as normal elimination. The weekly elimination when averaged and divided by the total amount of radium in the body at death gives as the coefficient of weekly elimination for rat No. 2, 0.42 per cent and for rat No. 3, 0.62 per cent.

If the last two weeks were neglected in the case of rat No. 2, for the above reason, and the third and fourth weeks' excreta averaged and that value used in calculating the coefficient, the coefficient of weekly elimination for rat No. 2 would be 0.61 per cent which would check the value found in the case of rat No. 3.

We attempted no experiments to increase the normal rate of elimination in our experimental rats.

XIII. DISCUSSION

It is difficult to interpret the blood findings of these rats in the light of human blood pathology on account of the differences in numbers and proportions of the blood cells. The type of anemia produced in the injected rats might be compared in type with that produced by other chemical poisons such as lead, arsenic, benzol, etc. The decrease in red blood cells in rat No. 2 (to 2,000,000) represents an extremely anemic condition. The great rise in total white cells and neutrophil percentage in this rat just before its death shows that the body was still able to respond to a demand for these protective cells. Whether the majority of them came from the remaining hyperplastic marrow or from the other organs which had taken over the function of forming granulocytes is not known.

The extramedullary myelopoiesis seen in the spleen, lymph nodes, and to a lesser degree in the liver, and the hyperplastic condition of the marrow in the central parts of the shafts of the long bones represent an attempt to compensate for the aplastic condition of the rest of the marrow. The greater concentration of radium in the ends of the bones accounts for the earlier destruction of the marrow at these points.

Lymphocytes were destroyed in large numbers. The fixed lymphocytes in the spleen, lymph nodes, etc., were decreased much more proportionately than were the circulating lymphocytes. Many of the lymphocytes were converted into plasma cells which are a common reactive cell in certain chronic diseases. The increased number of lymphoblasts perhaps is indicative of a shorter life period of the lymphocytes.

The mucus-secreting cells of the submaxillary glands and the cells of the medulla of the suprarenal glands were more susceptible to injury than were the other cells of these glands.

Pneumonias may have been the direct cause of death in some of the rats, but in most cases they seemed hardly extensive enough for this.

The infection by pyogenic bacteria as found in the lungs of some of the rats and around the mandibles of all the rats is definitely the result of the lowered resistance of the animals.

The compressed, homogeneous-appearing cells of the liver, some of them with pycnotic nuclei, indicate a decreased secretory and storage function of this organ.

The non-inflammatory, degenerative changes in the heart muscle represent a toxic myocarditis or a myocardosis with the fibrous tissue replacement as the healing process.

The kidneys show the changes of an acute parenchymatous nephritis plus numerous areas of calcification. The location of the lesions in the convoluted tubules and thick segments of Henle's loops definitely establishes toxins which have been passed into these tubules as the etiological agents.

One would suspect that associated with the marked changes in the calcification of the skeleton there would be some changes in the parathyroid gland, but such was not found to be the case.

The females were definitely not rendered sterile by the treatment but some condition

was induced which prevented normal gestation.

The males may or may not have become sterile. Large numbers of apparently normal sperm were being formed but whether or not they were physiologically potent is not known. The degenerative changes that had occurred in the testis indicate that the male rats would have been sterilized had they lived long enough.

Just why the histological changes in bone are most marked at the costochondral junctions and sterna is not known, but the sudden change from bone to cartilage may have something to do with it.

The hyperplasia of the periosteum and endosteum at the above mentioned places may indicate an irritative condition or may be a compensatory reaction. The cause of the caries and necrosis of soft tissue in these regions of the skeleton is not clear, but is more than likely due to a localized relatively high concentration of radium. The fibrous tissue replacement and granulation tissue ingrowth is the normal process of healing where tissue has been destroyed and removed.

Both ante-mortem and post-mortem findings show that there was a marked decrease in calcified bone in the central part of the bones (which accounts for the pathological fractures), and an increase in calcified bone around the joints. This indicates some sort of disturbance in the osteoblast-osteoclast balance. Just why there is a greater than normal concentration of calcium around the joints and less than normal concentration in the central parts is not known.

Schlundt and Failla have questioned the prevailing idea that the distribution of radium in the bony skeleton is fairly uniform. The work of Flinn and Seidlin (1929) was based upon the assumption that calcium and radium are metabolized in the animal system in a similar manner. We hope that some of our experimental results will help to clear up some of these points.

Calcium and radium are both members of the alkaline earth group of the periodic system. Lehnerdt (1909) has shown that strontium, another homologue of this group, can be substituted in the animal system for calcium. Radium in the animal system has a strong tendency to form salts, such as sulphates, phosphates, and carbonates. Lind, Underwood, and Whittemore (1918) found the solubility of radium sulphate to be 2.1×10^{-8} grams per cubic centimeter. A normal rat with a blood volume of approximately 20 c.c. could dissolve only 4.2×10^{-7} grams of radium sulphate, which is less than one-seventeenth of each injection of radium. Hence, it follows that the injected radium chloride will be converted into the insoluble sulphate immediately, which then precipitates in the blood and eventually is deposited in the bone. This deduction remains to be established by experiment. We did not make radium determinations on the blood of the live rats; however, the highly vascular tissue at autopsy showed only slight radium content.

By analysis of the parts of the animal system it was found that over 99 per cent of the radium in the entire body was contained in the bone ash. Since practically all of the calcium in the body is contained in the bone, which is maintained by the deposition of calcium salts, a parallel between the paths of radium and calcium in the system seems to be the logical explanation for this similarity of location.

The bone ash of an albino rat generally has a calcium content of approximately 39 per cent, which is rather uniformly distributed in the bones of the skeleton. Since the radium analysis of the various bones, with the exception of the mandibles, also showed a uniformity in the distribution of radium in the bones of the skeleton, it is very likely that in an individual animal there is a definite ratio between the radium and calcium everywhere in its skeleton. After the administration of radium is stopped, this ratio slowly decreases due to the small quantity of radium that is being eliminated normally. Perhaps it is not too bold an assumption to say that the rate of radium elimina-

tion serves as an index of the normal calcium turn-over in the bones.

The concentration of radium in the mandibles was found to be only 65 per cent of that in the ash of the other bones of the skeleton. The teeth from the mandible of a radioactive rat were analyzed separately from the remainder of the bony portion. The concentration of radium in the ash of the teeth was found to be only 27 per cent of the concentration found in the ash of the teeth-free portion. The concentration of radium in the ash of the total mandible was consequently reduced to 70 per cent of the concentration in other parts of the skeleton. These results establish that the low concentration of radium in the ash of the mandibles is due to the relatively low concentration of radium in the ash of the teeth, which make up the majority of the weight of the total ash.

The roentgenograms and the radiographs show similar concentrations respectively of calcium and radium at the knee joints and at the ends of the vertebrae. This close similarity further verifies the assumption that a definite radium-calcium ratio is established in an individual animal.

The fetuses of the radioactive female were found to contain a small amount of radium. In the growth of the embryo, a transfusion of calcium and other salts takes place between the two systems. Since the concentration of the radium in the ash of the fetuses is only 3.6 per cent of that found in the ash of the parent, the salts used in the nutrition of the fetuses must have had a lower radium-calcium ratio than the bone ash of the parent. Therefore, since radium had not been administered to the parent after pregnancy, we may assume that the calcium in the fetuses in all probability was metabolized in the ratio of 28 parts from the nurture of the parent to 1 part from the bone of the parent.

Of the organs that were tested for activity, the kidneys and the intestines had a concentration of radium from two to ten times greater than the others. This result is not so surprising since metabolism of calcium is one of the functions of these organs.

If the inactive period just prior to the death of the animals is disregarded, the normal weekly elimination of radium, several weeks after the administration and a few weeks before death, was found to be 0.62 and 0.61 per cent, respectively for the two rats where coefficients of elimination were measured. Schlundt and Failla (1931) found values of 0.035 and 0.017 per cent respectively for the normal weekly elimination of two girls who had become radioactive twelve years before their normal radium elimination was determined. Seidlin and Flinn (1929) produced a 50 per cent elimination of the fixed radium in several radioactive patients by parathormone treatment which extended over a two to five month period. Our value for the weekly elimination of radium by rats, which is approximately twenty times greater than the value found by Schlundt and Failla in humans, would require an amazing increase of over 400 per cent over the weekly elimination to obtain a 50 per cent elimination in a five months' period. In our experimentation, we did not attempt to produce an abnormal rate of elimination, but our results on the normal rate of elimination of radium should help to form a basis for any future attack of this problem.

The radium which is present in the bone disintegrates and expends much energy in the form of radiations. Ninety per cent of the energy set free resides in the swift alpha particle. This alpha particle is a helium nucleus, which is an anion containing four protons and two electrons in a compact mass. In spite of its comparatively great mass it has an initial velocity of from one-twentieth to about one-twelfth that of light. Because of its high kinetic energy it is capable of disrupting molecules, of producing ionization in gases, and of decomposing liquids into their constituent elements. These chemical changes are brought about by the collision of the alpha particle with atoms, which cause electrons to be ejected from their orbits and in rare instances cause the ejection of a proton from

the nucleus of the atom. Since the alpha particle is massive for a sub-atomic radiation of high speed, it is stopped in a relatively short distance in dense material, but only after the expenditure of its energy, which in the case of the alpha rays from radium C′ is 1.5×10^{-5} ergs per particle. The range over which this ionization by the alpha particle takes place in the tissue is approximately 0.1 mm.

The alpha particle arising from the disintegration of radium in the system is only one of four alpha rays produced in the system, three of which originate from the disintegration of the decay products of short life, radon, radium A, and radium C′. The disintegration of radium itself occurs in the bone, but the radon that is produced by this disintegration, while it remains in part occluded in the bone, some of it emanates from the bone, enters the blood and thus circulates throughout the system continually producing radium A and radium C′. Each transformation is accompanied by the emission of a destructive alpha particle. Therefore, the radon and its short-lived radioactive products in circulation give rise to powerful projectiles not entirely localized in the bone but distributed in all parts of the body. We are assuming that the emanating power of the bone in the living rat has a value not differing materially from that of 35 per cent found for the air-dry bone.

A rat containing only 15 micrograms of radium in its system absorbs over 2,000,000 alpha particles per second. The 25 ergs of energy so produced exercises a disturbing physiological effect upon the system of the animal. The greater portion of these radiations is concentrated upon the marrow and the immediate tissue. Not only do the bone cells receive the disruptive effect of most of the alpha rays but they also receive the shock of the recoil atoms. The combined effect might cause the destruction of cellular matter, which would be carried away in solution, leaving the bone brittle and fragile.

Since the blood cells are affected very shortly after the radium has been injected, the radiations must immediately produce their physiological effect on the blood protoplasm. Some radium and some radon are in the blood as long as there is radium in the system, therefore the blood cells throughout the system are subject to continual bombardment by alpha particles.

The blood cell, consisting of several thousand protein molecules, is a colloidal micella in which the stability is maintained by polar linkage between the molecules. The usual diameter of a red blood cell is about 7 microns. The protein molecules in the micella are massed together in a particle of which the outer layer is ionized. The stability of the micella in solution is maintained by a potential between this layer of ions and oppositely charged layer bathing the cell. This potential, known as the zeta potential, must be sufficiently high or coagulation will occur. The potential at which coagulation will just occur is known as the critical potential. The zeta potential depends upon the distance between the ion layers of the micella and the quantity of charge in each layer; the reduction of either of these will tend to decrease the zeta potential to the value for the critical potential where coagulation of the micella will be effected.

Since the penetrating rays from radium are known to coagulate certain suspensions and emulsions, it is plausible to assume that the relatively greater energy of the alpha particle is effective in coagulating colloidal particles such as blood corpuscles. The colloidal systems of erythrocytes are strongly electronegative which would allow coagulation to occur if the outer positive layer of ions were neutralized to an extent that the zeta potential was lowered to a value below the critical potential. The alpha particle in passing through the cell would cause electrons to be ejected from the interior of the cell to the outer positive layer which would cause a decrease of the zeta potential and cause the micella to coagulate or be absorbed by another cell. Hence, the red cells would be more liable

to damage by radiations. This explanation of the extermination of the cell shows that more than one alpha particle would be necessary to produce effect enough to coagulate a cell.

The disruption of molecules in the cell could be brought about by the energy of the alpha radiation. The polar links that hold the molecules together are weaker than ordinary atomic linkages and can be broken apart with the expenditure of energy in the magnitude of 10^{-21} ergs per molecule. The alpha particle with an initial kinetic energy of 1.2×10^{-5} ergs has a maximum possibility of producing in the neighborhood of 10^{8} such disruptions along its path through the material. Again the linkage between the carbon atoms of the protein molecules have an energy content of the magnitude of 10^{-19} ergs per linkage, which could be disrupted at the rate of one million per alpha particle as a maximum possibility. It appears then that the disruption of cells would be accomplished at an astounding rate, but it must be remembered that in practice it is probably a more complicated process than the one here outlined. We regard it as an inviting field for further investigation.

XIV. SUMMARY

1. Eight albino rats, four males from one litter and four females from another litter, were injected subcutaneously with doses of radium chloride ranging from 40 to 60 micrograms administered over periods of from 126 to 191 days. The life periods of the rats following the first injections of radium ranged from 183 to 258 days in the different rats.

2. A typical secondary anemia occurred in the injected rats; the red blood cells in one going as low as 2,000,000 per cubic millimeter (10,000,000 is normal).

3. The injected rats gained weight more slowly than the controls and, before death, lost weight very rapidly.

4. There was a decrease in calcification in the central portions of all the bones and a concentration of calcium salts in the parts of the bones nearest the joints. This softening of the central parts of the bones predisposed to several pathological fractures.

5. There were abscesses in the soft tissue around the mandibles of all the injected rats.

6. A hyperplastic bone marrow was present in the central two-thirds of the shafts of all the long bones. The extremities of the long bones and all the other bones contained an aplastic marrow.

7. There was a great destruction of lymphocytes in the spleen and lymph nodes and an increase in lymphoblasts, plasma cells, and giant cells. Extramedullary myelopoiesis was marked in the spleen and lymph nodes and to a lesser degree in the liver.

8. The cells of the mucous tubules of the submaxillary gland and many cells in the suprarenal glands were degenerating.

9. There was a non-inflammatory degeneration of the myocardium and some fibrosis in a few cases. The liver showed evidence of decreased functional ability. The kidneys showed an acute parenchymatous nephritis with numerous areas of calcification. The tubules of the testes were in various stages of degeneration.

10. Normal follicles were developing in all the ovaries. All thyroids, parathyroids and pancreases were histologically normal.

11. In several cases there were uneven enlargements of the costochondral junctions. These consisted of carious bone being replaced by fibrous tissue from a highly hyperplastic periosteum. In one rat there was a similar condition in the sternum.

12. Analyses of the post-mortem specimens of the rats definitely established that:

(*a*) Over 99 per cent of the retained radium was found in the bone ash.

(*b*) The bones taken from different sections of the body showed slight variation in concentration of radium, with the exception of the mandibles, which had about 60 per cent of the concentration of the other bones.

(*c*) The organs dealing with calcium metabolism, the kidney and the intestines,

were found to contain higher concentration of radium than the remainder of the soft tissue.

(*d*) The concentration of radium in the fetuses of a radioactive female rat was shown to be only 3.6 per cent of the concentration of the parent.

13. A study of the radiographs, produced by radium rays from the bones, showed the concentrations of radium at the knee joints and the ends of the vertebrae similar to the concentration of calcium at these places shown by the roentgenograms.

14. The quantity of retained radium was determined for each rat giving an average retention of 24.6 per cent. Correlation of this quantity could not be established with any of the following points: (*a*) the quantity of injected radium, (*b*) the life span after the start of the injections, and (*c*) the sex of the rat.

15. The elimination of radium immediately after the injections was determined. Approximately 50 to 65 per cent of the injected radium was eliminated one week after the first injection. The normal elimination of radium was established for two of the animals to be 0.6 per cent per week.

16. The type of rays that might have been effective in producing systemic changes in the animal has been discussed. We have also discussed a conjecture relative to the path of the radium in the system and the effect of the radiation on the tissue.

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SKIN ERYTHEMA DOSE IN TERMS OF ROENTGENS IN SUPERFICIAL THERAPY*

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SINCE the adoption of the international roentgen, r, little if any work on the relation of skin reactions to given quantities of roentgen radiation of the qualities generally used in dermatological therapy, has been presented, in the United States, in terms of this new unit. The pioneer investigations of Meyer and Glasser, as well as the later work of Meyer and Braestrup, were done prior to the adoption of the international roentgen. The measurements made by them were based upon the German R, as first employed in this country by Glasser. Unfortunately, this unit, as applied here, appears to have been considerably smaller than the actual German R, thereby complicating present interpretations of their work.

The adoption of the international roentgen having definitely established the physical unit of roentgen-ray quantity, we undertook to investigate its biological significance in relation to the skin. By clinical experiments upon the human skin we attempted to determine the number of roentgens equivalent to an erythema dose, and whether this number was influenced by different qualities of radiation.

EXPERIMENTAL FACTORS

The tests were carried out on 24 patients who were being treated for acne. Areas of healthy skin on the anterior surfaces of the thighs were exposed to various doses of from 350 to 550 r measured without back-scattering. Two sets of factors were employed as given in Table 1, each representing a type of radiation commonly used by us in the treatment of skin diseases. Grenz rays are not included.

TABLE 1
SUMMARY OF PHYSICAL FACTORS USED

λ min. A.U.	kv. Pulsating Potential	ma.	Filter	Half-Value Layer Ray Quality		Focus-Skin Distance cm.	Average Intensity r/min. in air	Field 7.5 cm. diam.	Back-scattering Factor
			Al mm.	Cu mm.	Al mm.				
Set-up A									
0.13−	100	6	0	0.029	0.58	50	61.5	44.1 cm.²	1.075
Set-Up B									
0.09+	135	5	3	0.198	(5.25)	50	17.0	44.1 cm.²	1.138
a	b	c	d	e	f	g	h	i	j

a. Minimum wave length determined by means of the Seeman spectrograph.
b. Crest value of the tube voltage as measured with sphere gap; spheres 15 cm.
c. Reading of milliammeter in high tension circuit checked by meter at ground potential.
e, f. Half-value layers in copper and aluminum as measured by large open-air ionization chamber. Figures in parentheses are calculated from the Cu value.
h. The r refers to the international roentgen as obtained at the Bureau of Standards through the calibration of a Wulf ionometer, and also through measurements with a large open-air iontoquantimeter calibrated in Germany.
j. Ratio of the intensities with and without back-scattering due to 7.5 cm. diameter field.

Set-up *A* produces the quality of radiation generally used in unfiltered roentgen therapy in dermatology. Set-up *B* gives the quality of radiation commonly employed for filtered superficial radiotherapy, 3 mm. of aluminum being used.

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A series of preliminary tests was made with unfiltered radiation (ray quality *A*), doses of 350, 400, 450, 500 and 550 r being used. These tests indicated that 350 r usually did not provoke a skin erythema, whereas an erythema was visible with surprising uniformity after 400 r, and that larger doses (450, 500, 550 r) caused intense reactions which were greater than we would expect from an erythema dose. The latter may be defined as the smallest amount of radiation that consistently and uniformly will produce a pale pink skin reaction (erythema) which generally appears a few days after exposure and lasts for about two weeks, these characteristics being influenced by the quality of the radiation and by the type of skin of the patient, the location and the size of the area treated, etc.

Twenty fields were exposed to 400 r, 100 kv. with unfiltered radiation being used in accordance with set-up *A* and an equal number of fields were irradiated, the same dose, 400 r, being given, but with set-up *B*, 135 kv. being used with a filtration of 3 mm. of aluminum. Each patient was irradiated with both roentgen-ray qualities, one on each thigh. The same equipment and tube were employed in both series of tests. A pulsating potential generator with mechanical rectification energized a thin-walled deep therapy Coolidge tube. The roentgen tube was completely enclosed in a lead-lined drum except for the aperture. An open cone in contact with the patient insured exact focal skin distance and uniform size of field. Two milliammeters, one in the high tension circuit and the other at a ground potential, provided a continuous check on the tube current.

The desired tube potential was established by spark gap measurements by the use of 15 cm. spheres. The corresponding primary voltage was noted and maintained during each irradiation. The radiation output was measured each time with a thimble chamber type Wulf ionometer calibrated in international roentgens at the United States Bureau of Standards. A further check on the accuracy of the instrument was obtained by comparing it with another large open-air type chamber which had been previously calibrated in international roentgens in Germany. A difference of less than 3 per cent was found between the two calibrations. The quality of radiation was established with the open-air type chamber and checked routinely with the Wulf instrument. The voltage sensitivity of both instruments was verified by means of radium controls.

The greatest intensity variation between successive radiation measurements was found to be 4.8 per cent, indicating that any error due to changes in radiation output was less than this figure. Furthermore, as any variation in intensity was in the same direction for both roentgen-ray qualities, the relative error was even smaller. In any case the accuracy of the physical factors exceeded by a wide margin the precision possible in the observation and judging of the skin changes.

The quality of radiation is indicated not only the voltage and filtration but also by the half-value layer in aluminum and copper, as the first two factors alone, as is well known, do not accurately express the penetrability of the rays. In the past this has been primarily due to the variations in the voltage wave form of various types of equipment. At present, another factor, the filtration effect of the glass wall of the roentgen tube, should receive consideration because of the introduction of the heavy pyrex glass roentgen tubes. The additional filtration of the glass wall of this new type of high voltage therapy tube is approximately equivalent to 1.5 mm. of aluminum at 100 kv.

The radiation quantity is indicated without back-scattering, as all the routine measurements were made in air with avoidance of secondary radiation. Tests made with the thimble chamber half immersed in water indicate that with a field of 7.5 cm. diameter the back-scattering was 7.5 and 13.8 per cent of the primary intensity for the ray qualities *A*, and *B*, respec-

tively. The total dose received by the skin was therefore $400 \times 1.075 = 430$ r for ray quality *A* and $400 \times 1.138 = 455$ r for ray quality *B*. In other words, the skin actually received greater physical dose for the higher roentgen-ray quality although the primary radiation quantity was the same in each case.

RESULTS

In all of the test areas exposed to 400 r with set-up *A* or set-up *B*, there resulted a faint erythema. This varied slightly in intensity, time of onset and duration, with different patients. The erythema was deeper with set-up *A* (unfiltered radiation) than with set-up *B* (through 3 mm. of aluminum filter) in 10 out of 20 cases; the two were of equal intensity in 4 cases, and the erythema with set-up *A* was less than that with set-up *B* in 6 cases.

COMMENT

The number of cases is too small to make a basis for general conclusions regarding the effect of quality on the intensity of the skin reaction. The differences in the intensity of the erythemas might be accounted for by individual variations in the skin sensitivity of the various patients. However, the figures tend to suggest the possibility that the longer wave lengths cause more intense skin reactions than the shorter wave lengths, the number of roentgens being equal. This would be in conformity with the observed erythemas of patients receiving regular roentgen therapy for dermatological lesions in private practice and at the clinic. Similarly, the number of roentgens considered equivalent to an erythema dose in deep therapy is considerably higher (600–650 r) than applied in superficial therapy.

The question of the influence of quality upon the number of roentgens per erythema has caused wide differences of opinion. Contrary to Meyer and Glasser, and others who found that the roentgens per erythema varied with the roentgen-ray quality, Holthusen, as well as Hess, found the same skin reaction for a given dose over a wide range of roentgen wave lengths. A review of this question is particularly well presented in an article by Glocker, Hayer and Jüngling. Using small fields, 1.5×1.5 cm., and two roentgen-ray qualities (80 kv., 3 mm. fiber and 180 kv., 0.7 mm. copper), they found the softer radiation causing stronger skin reactions when small doses were given. However, using what they called full doses (700 R), they found no consistent biological differences between the two types of radiation.

It is interesting to compare the size of the fields used with the findings of the various investigators of this subject. Meyer and Glasser used large fields and found wide differences in the roentgen per erythema according to wave length. Glocker used extremely small fields and reported no material biological differences between the soft and hard radiation as employed by him.

With the use of medium-sized fields our results tend to show some effect of the wave length upon the erythema produced with equal doses of roentgens. This suggests that the size of the field has a bearing upon the question and that the differences in the skin reactions due to wave length increase with the size of the field.

We were impressed by the uniformity of our clinical results from employing 400 r with set-ups *A* and *B*. Each of the erythemas that regularly appeared after these exposures was definite but very faint, with minor variations in intensity, as before mentioned. With smaller amounts of radiation (350 r), erythemas were not obtained, and with larger amounts (450, 500, 550 r) intense erythemas were regularly noted.

CONCLUSIONS

The results of our work tend to show:

(1) The skin of various patients responds to equal physically measured doses of roentgen radiation with surprising uniformity, the same roentgen-ray quality and the same experimental conditions being used.

(2) With medium-sized fields (7.5 cm. diameter) 400 roentgens measured in air are equivalent to an erythema dose, with the two qualities of roentgen rays most commonly employed in dermatological therapy. The skin reaction seems to be slightly less intense for the shorter wave lengths (that is, filtered radiation) than for the unfiltered rays of longer wave lengths. The influence of the wave length becomes greater as the size of the field is increased.

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VOL. XXIX, NO. 5

THE ANALGESIC EFFECT OF ROENTGEN RAYS IN METASTASIS FROM CARCINOMA OF THE PROSTATE GLAND

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IN recent years roentgen rays have been employed in the treatment of carcinoma of the prostate gland, but, so far as regression of the tumor is concerned, it is generally agreed that the results are far from satisfactory. However, if one aims only at temporary relief of pain caused by the carcinoma, which sometimes makes the patient's last months of life unbearable, roentgen treatment is often beneficial. The analgesic property of roentgen treatment in cases of carcinoma of the prostate gland assumes great importance, since pain is the major complaint in more than 60 per cent of such cases.

The deep situation of the prostate gland and the anatomy of its lymphatic system well explain the development of pain; in fact, the nerves of the sacral and lumbar plexuses are so near the primary tumor or the metastatic nodes that compression and irritation may easily occur.

Rouvière (Fig. 1) stated that the lymphatic vessels of the prostate gland originate among the glandular acini; they then reach the periphery of the organ where they form a subcapsular plexus. Four lymph vessels leave this plexus; one vessel goes toward the bladder and reaches the external iliac nodes; a second takes a posterior direction and ends in the hypogastric group; a third reaches the lateral sacral node, and a fourth descends to the floor of the pelvis to terminate in the hypogastric group.

The invasion of the nodes by carcinomatous cells from the prostate gland occurs early and is practically constant. Dossot reported that in 36 of 38 cases of carcinoma of the prostate gland, involvement of the lymph nodes was as follows: abdominal, 86 per cent; hypogastric, 55 per cent; iliac, 50 per cent; external iliac, 44 per cent; pelvic, 13 per cent, and inguinal, 1 per cent. The

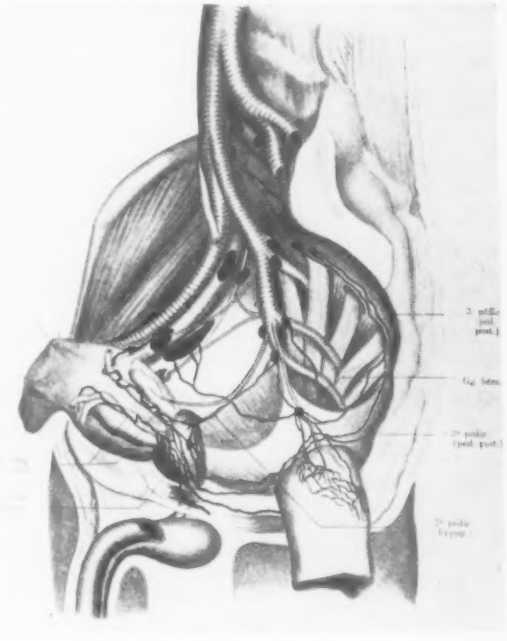

FIG. 1. The lymphatic vessels of the prostate gland (after Rouvière).

compression of nerve trunks by enlarged lymph nodes is not, however, the only cause of pain. Pain may also be caused by metastasis to bones.

Until within recent years metastasis to bone in cases of carcinoma of the prostate gland was not frequently found at necropsy, since small lesions confined to the marrow were often missed in routine examinations of the skeleton. However, Kauf-

mann reported recently that he had observed involvement of bone in 16 of 22 post-mortem examinations in cases of carcinoma of the prostate gland. Roentgenography offers a more accurate and easier method of identification. In 1926 Bumpus, by this method, found that metastasis to the bones occurred in 30 per cent of his cases, and many other observers have noted similar percentages. Perhaps even high percentages could be found if complete roentgenologic examination were made of the skeleton of all patients in the late stages of the disease.

TABLE 1

ONE HUNDRED CASES OF CARCINOMA OF THE PROSTATE GLAND WITH METASTASIS TO BONE

Involvement of the prostate gland (clinically)	
Right lobe	11
Left lobe	14
Middle lobe or both	75
Site of metastasis to bone (by roentgen rays)	
Pelvis	63
Spine	42
Femur (upper)	7
Ribs	3
Skull	1
Other sites of metastasis (clinically and by roentgen rays)	
Abdominal nodes	8
Inguinal region	2
Supraclavicular region	2
Axilla	2
Lungs	3

The bones most frequently involved by carcinoma of the prostate gland are the pelvis, the lower part of the spine, the upper part of the femur, the sternum, ribs and skull, the bones in which red marrow persists through life. This factor is supposed to be of great significance in determining the situation of metastatic lesions from carcinoma in bone.

Another definite cause of pain is the invasion of the perineural lymphatic vessels by the carcinomatous cells which as Ferguson has noted, occurs in 52 per cent of cases.

In order to observe the relationship between clinical symptoms and anatomic lesions we reviewed the histories in 100 cases, taken at random from the records of cases of carcinoma of the prostate gland and metastasis to bone (Table 1).

Pain was present in 75 cases: in the right hip and leg in 14, in the left hip and leg in 12, in both hips and legs in 26, in the back in 21, in the lower part of the abdomen in 7 and in the thorax in 3.

The histories did not contain reference to any constant relationship between the site and extent of involvement of bone and the presence and intensity of pain. In 3 cases marked involvement of the pelvic bones of one side was disclosed by roentgenograms, although the pain was on the opposite side. In these cases the pain was probably due to carcinomatous enlargement of lymph nodes which were invisible in the roentgenograms and too deeply seated to be discovered clinically, or to invasion of perineural lymphatics. In 25 cases there was no pain, in spite of extensive metastasis. These observations suggest that pain does not always indicate involvement of bone.

The favorable response of pain to roentgen treatment is well known. Although the mechanism by which the analgesic effect is produced is not clearly understood, because the subject is one which hardly lends itself to animal experimentation, there is no doubt clinically that irradiation produces such an effect on a great variety of lesions, both inflammatory and neoplastic. The effect is most easily explained by assuming a direct destructive action on cells which press on or irritate the nerves. The degree of response depends on the radiosensitivity of the infiltrating benign or malignant cells and on the involvement of the sensory nerves.

In order to determine the analgesic effect of roentgen rays in cases of carcinoma of the prostate gland with metastasis to bone, 40 cases treated in the Section on Therapeutic Radiology in the last few years were reviewed. This number of cases was selected for comparison with 40 cases of

carcinoma of the breast with involvement of bone which had been previously studied from the point of view of the analgesic action of roentgen rays.

All of the patients complained of severe pain of long duration in the back or along the sciatic nerves, and this was the main indication for treatment. The general condition of the patients was often so poor as to exclude such radical measures as cordotomy or ramisectomy. The roentgen treatment had to be given slowly, in order to avoid severe reaction. One field daily was usually well tolerated. The technique varied in different cases but was generally as follows: Cross firing of the pelvis through four large fields (one anterior, one posterior and two opposite lateral fields) at high voltage;* cross firing of the spine through large fields at moderate voltage** on each side of it, the beams converging at an angle of about 45° (Fig. 2). Complete relief occurred in 3 cases (from one to seven months). There was marked but incomplete relief in 21 cases, and no relief in 16. The relief lasted one month in 8 cases, two months in 12 cases, six months in 3 cases, and one year in 1 case.

Exceptionally relief from pain was obtained before the end of a course of treatment, but usually it occurred from the tenth day to the second week. Our experience seems to confirm the results obtained by others and tends to establish the fact that relief from pain does not always follow roentgen irradiation in cases of carcinoma of the prostate gland. In carcinoma of the breast, pain caused by metastasis to bones or to lymph nodes with pressure on or infiltration of lumbar nerve roots is relieved in a greater percentage of cases. Such a difference seems to support the idea that the analgesic action of roentgen rays is secondary to the destruction of neoplastic cells, because it is generally accepted that carcinoma of the breast is usually more radiosensitive than carcinoma of the prostate gland.

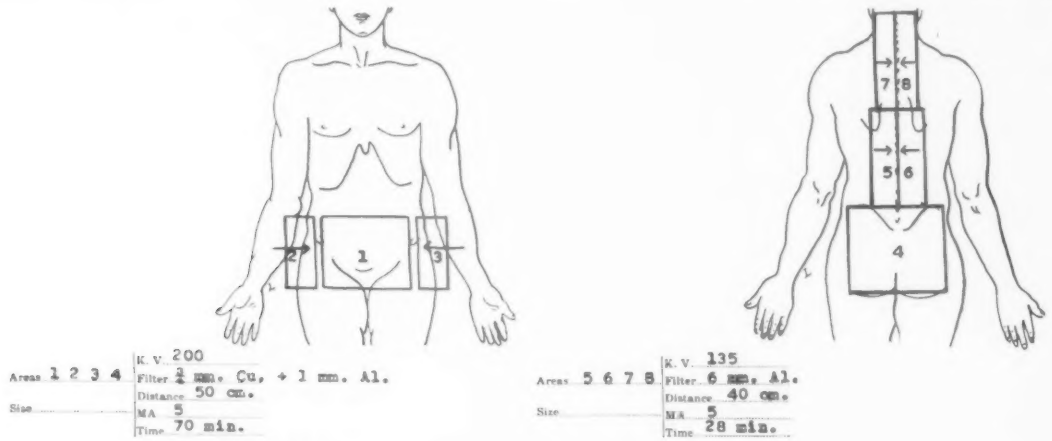

FIG. 2. The distribution of fields in a case of pelvic and vertebral involvement.

In spite of the fact that favorable results are obtained only in about half of the cases, roentgen treatment has a definite place in the treatment of pain from carcinoma of the prostate gland; it offers a somewhat uncertain, but readily tolerated, method of giving some patients palliation which otherwise could be obtained only by increasing the dose of sedatives or by radical operations on the nerves.

SUMMARY

A beneficial effect from roentgen treatment is obtained in about half the cases of pain from metastasis in cases of carcinoma

* High voltage: 200 kv., 5 ma., 50 cm. target skin distance, 0.75 mm. Cu+1 Al, 60–70 min.

** Moderate voltage: 135 kv., 5 ma., 40 cm. target skin distance, 6 mm. Al, 25–30 min.

of the prostate gland. This is in accordance with the well-known radioresistance of this disease.

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Vol. XXIX, No. 5

FRANCIS HAUKSBEE

DID HE, IN 1709, SEE HIS HAND THROUGH SEALING-WAX AND PITCH?

(With a repetition of the experiments)

By A. W. CRANE, M.D.
KALAMAZOO, MICHIGAN

FRANCIS HAUKSBEE is unquestionably the most noteworthy of the early pathfinders on the research trail of the x-ray. This trail was blazed by a long succession of discoveries and experiments beginning with amber, the lodestone, and the vacuum. The lodestone, or natural magnetic iron ore, made a profound impression on medieval philosophers. It was this strange power to attract iron that drew their sterile attention to the analogous power of amber, when rubbed briskly, to attract chaff, feathers, thread and, in fact, almost any light body. This apparently trivial effect of friction on amber was in fact known in prehistoric times but centuries had to pass and it was not until Dr. William Gilbert, physician to Queen Elizabeth composed his famous work "De Magnete" that scientific notice was given to this phenomenon. This is astonishingly recent considering human history; nevertheless, another century had to pass before Hauksbee appeared on the scene. This was in 1705, only seventy years before Benjamin Franklin signed the American Declaration of Independence.

Gilbert was the first to use the term "electrical," from the Greek word for amber. He therewith designated the attractive force exhibited by amber and, as he demonstrated, by many other bodies when rubbed by the dry hand or cloth. The miniature sparks also resulting from friction were not regarded as electrical but as a manifestation of fire which was believed to be inherent in all substances. It is hardly credible that this conception of electricity prevailed until the middle of the eighteenth century. Yet s'Gravesande in his "Natural Philosophy," a work of astonishing excellence and the recognized authority of that time, still contained in 1747, the following definition:

> "Electricity is that Property of Bodies by which when they are heated by Attrition they attract and repel light Bodies at sensible distances."

* * * * *

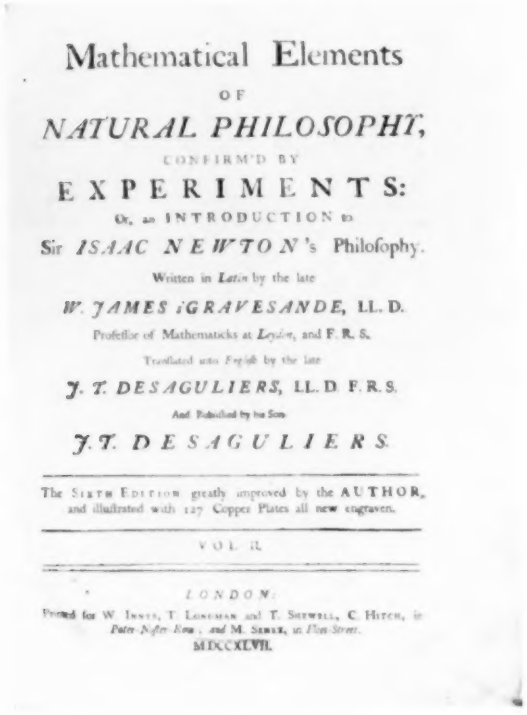
He continues:

> "I shall only mention a few Experiments, made about thirty years ago in England to make manifest the Connection between Electricity and Fire, if these two ought really to be distinguished."

These quotations give the actual state of electrical knowledge when Hauksbee began his investigations. The "Experiments, made about thirty years ago in England" refer to his work. That this work was not better interpreted seems due as much to indifference as to the conservatism of authority. Hauksbee had made this definition of electricity obsolete and opened the way for further research. Yet so slow was electrical progress that a knowledge of conductors and a conception of a current did not come for some twenty years after his death when Stephen Gray, an old man in a charity home, the London Charterhouse, drew attention by his historic experiments.

The particular interest of Hauksbee's work to roentgenologists lies in the fact that he was the first knowingly to excite a vacuum by electricity. The story of it illustrates the winding, halting, uncertain trail, by which scientific research picks its way. Fifty years before, in Italy, Torricelli, pupil and secretary of Galileo, experimented to find if air had weight. He closed one end of a glass tube about 35 inches long, filled it with mercury, inverted it so as to submerge the open end in a cup of

more mercury, and the column in the tube sank to about 30 inches, leaving an empty space above. Thus Torricelli proved the pressure of the atmosphere and incidentally invented the barometer. While the barometer is one of the most valuable of scientific instruments, yet it was the empty



Mathematical Elements
OF
NATURAL PHILOSOPHY,
CONFIRM'D BY
EXPERIMENTS:
Or, an INTRODUCTION to
Sir *ISAAC NEWTON*'s Philosophy.
Written in *Latin* by the late
W. JAMES 'GRAVESANDE, LL. D.
Professor of Mathematicks at *Leyden*, and F. R. S.
Translated into *English* by the late
J. T. DESAGULIERS, LL. D. F. R. S.
And Published by his Son
J. T. DESAGULIERS.
The SIXTH EDITION greatly improved by the AUTHOR, and illustrated with 127 Copper Plates all new engraven.
VOL. II.
LONDON:
Printed for W. INNYS, T. LONGMAN and T. SHEWELL, C. HITCH, in *Pater-Noster-Row*; *and* M. SENEX, in *Fleet-Street*.
MDCCXLVII.

FIG. 1. Title page of s'Gravesande's Natural Philosophy, 6th Edition, 1747, containing many of Hauksbee's experiments and four of his illustrations. (From the John Crerar Library, Chicago.)

space above that was to prove the more important, because this constituted the first permanent vacuum. The indirection of research was never better illustrated.

One night, thirty-four years later, Jean Picard, French priest and noted astronomer, carried a Torricellian barometer upstairs and noticed a luminous glow in the vacuum when the mercury was agitated. Like a true scientist he reported this observation. A fact once recorded can bide its time. Twenty more years passed, when Bernouilli, a professor of mathematics at Gröningen, came upon Picard's notes on the barometer, and experimented by shaking mercury in vials with and without exhausting the air. He produced considerable light which he called "mercurial phosphorus." Public interest was aroused when Bernouilli, using a mechanical shaker, thought he had invented a substitute for candles. Picard little dreamed that his feeble barometric glow would do as much as his astronomical observations to preserve his name.

The news reached England, and Francis Hauksbee, a new curator of experiments to the Royal Society, began an investigation of the phenomenon. His first papers, preserved in the Philosophical Transactions of the Society, deal with the explanation of "Mercurial Phosphorus." He proved that the glow or light was due to electricity resulting from the friction of mercury on glass.

These remarkable experiments would do credit to any modern research laboratory. To carry them out, Hauksbee invented a new type of air-pump, glass vacuum tubes and bell-jars, with stop-cocks, and mechanical devices for rotating his tubes. He experimented in many departments of physics, but fortunately for the world his chief attention was given to frictional electricity.

He was not the first, however, to experiment with air-pumps and the vacuum. His illustrious countryman, Robert Boyle, one of the founders of the Royal Society, had made his great reputation largely by such experiments. Boyle copied freely from von Guericke, the famous Burgomaster of Magdeburg, who invented the first air-pump and, independently of Torricelli, though about five years later, discovered the vacuum. Von Guericke was in fact the first to form a vacuum intentionally, Torricelli's vacuum being merely incidental to another demonstration. He was fired by the great theory of Copernicus and thought that air could not pervade all space, else planets would be slowed in their orbits by the resistance. He thereupon attempted to produce a sample of interstellar space in order to study it close at hand. He also in-

vented the first electrical machine—a rotated ball of sulphur, excited by the friction of the hand. Sparks were produced. This was a discovery of the first rank. But von Guericke, under the dominion of a cosmic theory, was absorbed in the fact that the excited ball would attract and hold all sorts of light objects such as chaff, bits of paper, foil, feathers, and so forth, thus simulating the gravitation of the earth. Both von Guericke and Boyle experimented with the vacuum and with electricity, but neither brought these two together. This was the great distinction reserved for Francis Hauksbee.

Hauksbee not only excited his vacuum tube by friction on the outside but also by a small friction machine placed inside ingeniously, so that it could be rotated without destroying the vacuum. He thus initiated the study of vacuum tubes excited by an electrical machine and definitely opened the trail that led finally to the x-ray, radio, amplifying tubes, neon lighting, the rectification of alternating currents, and all the vast array of effects depending on the action of electricity in vacuo.

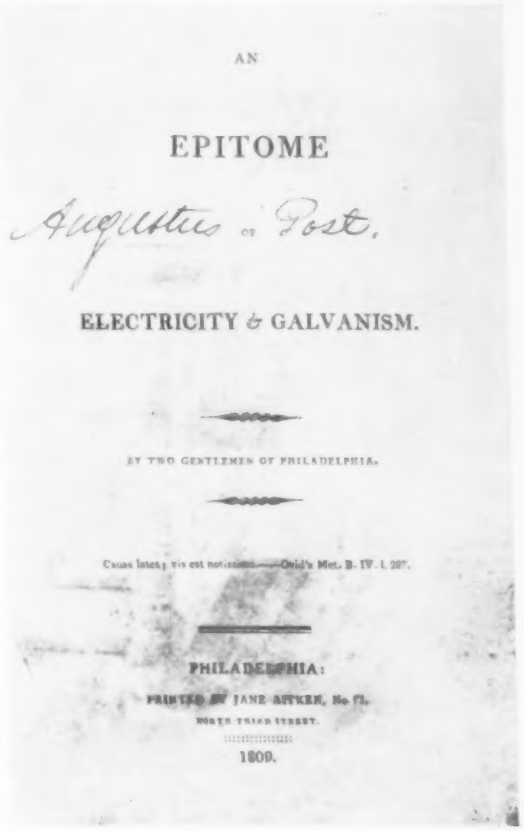
Following Hauksbee were Gray, Du Fay, Abbé Nollet, Franklin, Faraday, Crookes, Hertz, Lenard, and then Roentgen. Many other names, important connecting figures, could be added which, with those mentioned, are woven into this most fascinating story of scientific exploration and discovery, of experiment, theory and prophecy that have materialized in an age of electricity such as no imagination could have foreseen.

In 1912, at the annual meeting of the American Roentgen Ray Society, in Detroit, Dr. Edward H. Skinner made a notable exhibit of rare old books bearing upon the early development of electricity and the vacuum tube. Among these was a worn little volume whose title page read as follows:

"An Epitome of Electricity & Galvanism. By Two Gentlemen of Philadelphia. Printed by Jane Aitken, No. 71, Philadelphia, 1809."

Two paragraphs in the historical preface of this remarkable American book are of sufficient interest to roentgenologists to be quoted:

"Mr. Hawksbee, in 1709, wrote a treatise on electricity, and distinguished himself by discoveries which far surpassed those of his pred-


AN

EPITOME

Augustus a Post.

ELECTRICITY & GALVANISM.

BY TWO GENTLEMEN OF PHILADELPHIA.

Causas latere rei est notissima.—Ovid's Met. B. IV. l. 207.

PHILADELPHIA:

PRINTED BY JANE AITKEN, No. 71,

NORTH THIRD STREET.

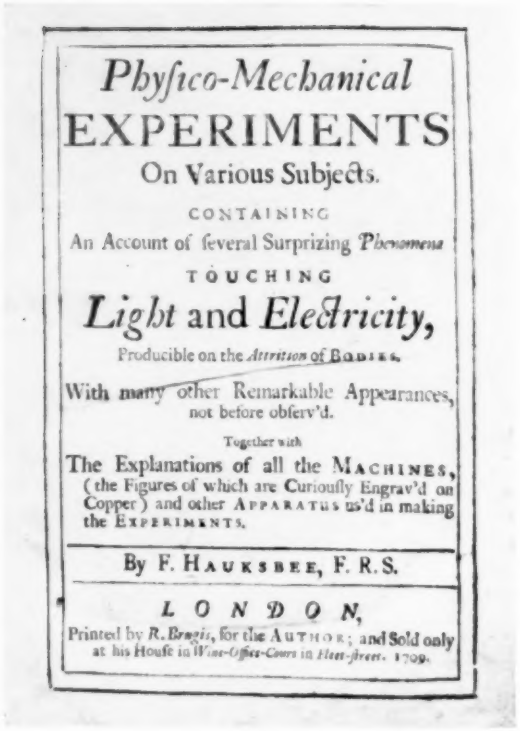
1809.

Fig. 2. Title page of first American History of Electricity. (By courtesy of Dr. Edward H. Skinner, Kansas City, Mo.)

ecessors. Besides a variety of new facts in regard to attraction and repulsion, he observed the electric light distinctly, and made some delicate and curious experiments on its nature."

* * * * *

"He made many experiments to show the extreme subtlety of the electric light, and found out a method of rendering opaque bodies transparent. He lined with sealing-wax more than half the inside of a glass globe, and having exhausted it, put it in motion. On applying his



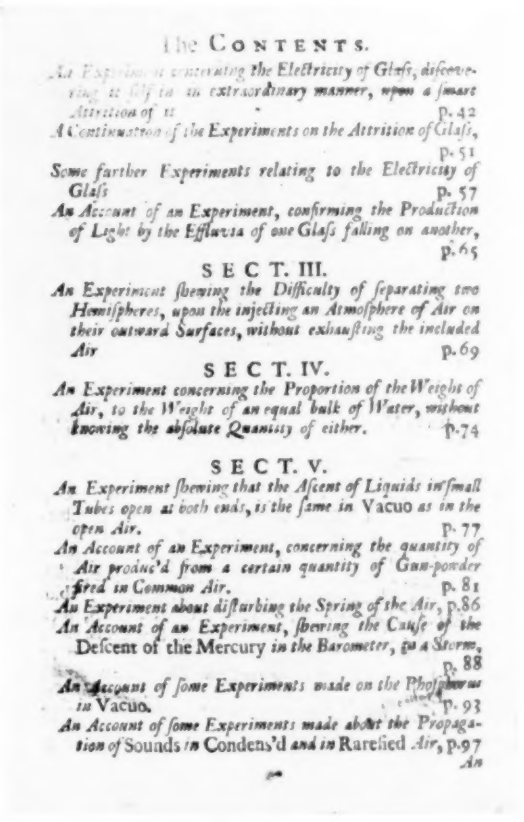
Phyſico-Mechanical
EXPERIMENTS
On Various Subjects.
CONTAINING
An Account of ſeveral Surprizing *Phenomena*
TOUCHING
Light and *Electricity*,
Producible on the *Attrition* of BODIES.
With many other Remarkable Appearances, not before obſerv'd.
Together with
The Explanations of all the MACHINES, (the Figures of which are Curiouſly Engrav'd on Copper) and other APPARATUS us'd in making the EXPERIMENTS.
By F. HAUKSBEE, F. R. S.
LONDON,
Printed by *R. Brugis*, for the AUTHOR; and Sold only at his Houſe in *Wine-Office-Court* in *Fleet-ſtreet*. 1709.

FIG. 3. Title page of first edition of Hauksbee's book, London, 1709. (From the Library of the University of Michigan.)

hand to excite it, he saw the shape and figure of all parts of his hand distinctly and perfectly, on the concave superficies of the wax within. It was as if these had been pure glass, and no wax interposed between the glass and his hand. This lining was in many places the eighth of an inch thick; and in some places where it did not adhere so closely to the glass as in others, yet the light on these appeared just as on the rest. He repeated these experiments with pitch instead of sealing wax and with equal success. It is to be regretted that these experiments have not engaged more of the attention of philosophers."

That this account of Hauksbee's work was copied from another author, even to the spelling of the name, "Hawksbee," was shown by reference to another valuable book in Dr. Skinner's collection, namely, the first "History of Electricity" ever written, published in 1768, by Joseph Priestley, preacher, chemist, discoverer of oxygen, and one of the most voluminous writers of any age. Priestley devotes considerable space to "Francis Hawksbee," evaluates his work highly, and after relating his experiments whereby sealing-wax and pitch are "rendered transparent," he adds: "They are really amazing and have not yet been pursued in the manner they deserve."

"Physico-Mechanical Experiments," by "F. Hauksbee," was published in 1709. This book is a compilation of his papers read before the Society and still preserved in its *Philosophical Transactions*. It was dedicated to Lord John Somers, Lord Chancellor of England, and a man of great learning, who had served as President of the Royal Society preceding Sir Isaac Newton. This dedication, while written in the fulsome, flattering style of the day, is



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Some farther Experiments relating to the Electricity of Glaſs p. 57
An Account of an Experiment, confirming the Production of Light by the Effluvia of one Glaſs falling on another, p. 65
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An Experiment concerning the Proportion of the Weight of Air, to the Weight of an equal bulk of Water, without knowing the abſolute Quantity of either. p. 74
SECT. V.
An Experiment ſhewing that the Aſcent of Liquids in ſmall Tubes open at both ends, is the ſame in Vacuo *as in the open Air.* p. 77
An Account of an Experiment, concerning the quantity of Air produc'd from a certain quantity of Gun-powder fired in Common Air. p. 81
An Experiment about diſturbing the Spring of the Air, p. 86
An Account of an Experiment, ſhewing the Cauſe of the Deſcent of the Mercury *in the Barometer, in a Storm*, p. 88
An Account of ſome Experiments made on the Phoſphorus in Vacuo. p. 93
An Account of ſome Experiments made about the Propagation of Sounds *in* Condens'd *and in* Rarefied *Air*, p. 97
An

FIG. 4. Page from table of "Contents" Physico-Mechanical Experiments, by F. Hauksbee, first edition, illustrating the variety of his experiments. Last reference in this edition is to p. 185.

mildly assertive in reminding Lord John that this work has "been already read and approved before the Society" and therefore "may with the Addition of your Lordship's Favour and Encouragement, hope to overcome all the Disadvantages of coming from the Hands of so underserving a Person."

The preface opens with the following:

"The learned World is now almost generally convinc'd, that instead of amusing themselves with Vain Hypotheses, which seem to differ little from Romances, there's no other way of Improving *Natural Philosophy*, but by Demonstrations and Conclusions founded upon Experiments judiciously and accurately made."

The first sections of this book contain most of the electrical experiments with which Hauksbee's name is associated. Then follows a succession of experiments in other fields which distinguishes him as a true physicist. We find him interested in the ascent of various fluids in small tubes and between plane surfaces closely approximated. He theorizes as to causes when there is no term like capillary attraction or surface tension yet to be substituted for an actual explanation. He is concerned with the weight of air, the freezing of water, the quantity of gas liberated by an explosion of gun powder, specific gravities and the refractive powers of fluids. A single page from his table of contents is given as an illustration. He places a clock in a vacuum chamber and demonstrates the necessity of air for the propagation of sound. He investigates compressed as well as rarefied air and suggests the possibility of liquefying air by pressure which, in 1709, was a far look ahead. He says:

"*What Kind of liquid would so many Atmospheres of* condens'd unelastic *Air compose?*

* * * * *

"*Is it impossible that Air by this means should become a* Visible Palpable *Fluid; and be subject to some of the same Management* that *other Fluids are?*"

Some of his findings would serve as subjects for post-graduate theses. For example he finds "that a Purple Light was produc'd by the Attrition of Glass on Woolen (in Vacuo)" and that different lights are produced in various ways. But he finds "*that Bodies which have yielded a particular Light, may be brought by Friction to yield no more of that Light.*"

"This is plain from the *strange and surprising loss of Purple* Colour, after two or three Trials made with the same Glass; for that *Purple* could not be recover'd by any Art or Means whatever."

* * * * *

"*Query.* Whether the *Loss* of Purple Colour be owing to the *Consumption* or *Retention* of matter?"

When a dispute arose between the French Academy of Science and the Royal Society of London regarding the refractive index of air in the use of telescopes, Hauksbee was ordered by the Royal Society to make the instruments of precision whereby the final test was made. This he accomplished in a highly satisfactory manner and tells it in an account that is slightly reminiscent of Benevenuto Cellini.

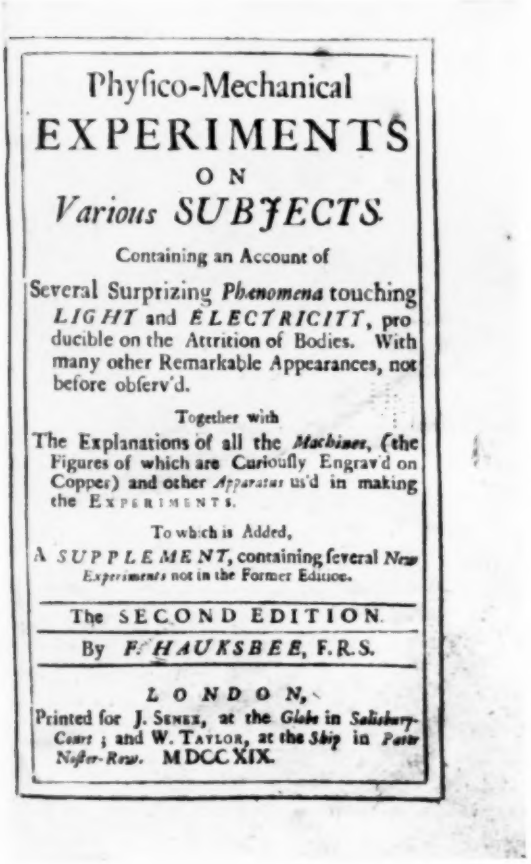
"The *Royal Society* (whose Glory it is to be as unwilling to deceive as to be deceived) being inform'd that this Experiment was call'd in question by the *French Academy*, were desirous that it might be put past dispute, by repeated and fully attested Trials. Accordingly, I was order'd to make an Instrument for the purpose, by the direction of Dr. *Halley*, R.S.S. and Professor of Geometry in Oxford."*

It is evident that he was regarded as the most competent maker of scientific apparatus in the England of his day.

Francis Hauksbee lived in the grand age of English Science, the age of Newton. The Royal Society to which he devoted the concluding years of his life, had become the greatest of all promoters and conservers of new learning. The year of his first recorded experiment was also the year when Newton became life president of the Society and received knighthood at the hand of Queen Anne. In America, we had just emerged

* Physico-Mechanical Experiments. By F. Hauksbee. Second edition, p. 226.

from the Salem trials for witchcraft, and the Rev. Cotton Mather was still the recognized intellectual leader. We are compelled, however, to add that, about the time of Hauksbee's death, Cotton Mather read a paper before the Royal Society and was



Physico-Mechanical
EXPERIMENTS
ON
Various SUBJECTS

Containing an Account of

Several Surprizing *Phænomena* touching *LIGHT* and *ELECTRICITY*, producible on the Attrition of Bodies. With many other Remarkable Appearances, not before obſerv'd.

Together with

The Explanations of all the *Machines*, (the Figures of which are Curiouſly Engrav'd on Copper) and other *Apparatus* us'd in making the EXPERIMENTS.

To which is Added,

A *SUPPLEMENT*, containing ſeveral *New Experiments* not in the Former Edition.

The SECOND EDITION.

By *F. HAUKSBEE*, F.R.S.

LONDON,

Printed for J. SENEX, at the *Globe* in *Salisbury-Court*; and W. TAYLOR, at the *Ship* in *Pater Noſter-Row*. MDCC XIX.

FIG. 5. Title page of second edition of Hauksbee's book, London, 1719. This edition was translated into French and Italian. (From the Library of the University of Michigan.)

elected a member, the first American thus distinguished.

Hauksbee was elected an F.R.S. in 1705, which is the date of his first paper. Before this date, nothing is known of him. He emerges from utter obscurity with this first paper and disappears as utterly with his last, which was printed in the Transactions posthumously in 1713, thus fixing the approximate date of his death. His name is not given in the Encyclopedia Britannica or Americana. In the Dictionary of National Biography (by Stephen and Lee) we find a notice of "Francis Hauksbee, the elder," which is merely a description of his book. Even the date of his birth could not be stated. We know nothing of his private life and fortunes. We have no letters, no portrait. The histories of the Royal Society are silent except for his scientific contributions. And it is doubtful if further traces of this remarkable man can ever be found now after the lapse of more than two centuries.

Concerning his education and habits we can surmise only. He must have been a man of learning and good reputation to have become a Fellow of the Royal Society. He probably had gained a competence, had shown skill as an experimenter and been ready to devote his whole time to scientific pursuits, because these are the stated requirements of a curator of experiments. His papers and book, the records of a brief career of about seven years, reveal him as an investigator of striking originality; an inventor of unusual mechanical skill; a keen, accurate observer; and a writer whose clear, candid style reflects the attitude of a true man of science. Although a close successor to Boyle and Hooke and a contemporary of Newton, yet he was not altogether overshadowed but was recognized by Park Benjamin as "a man of unusual genius in original research."

In 1719 a second edition of Hauksbee was issued and translated into French and Italian. That there should have been a demand for this second edition is surprising because public interest was restricted to a very limited section of the educated. After Hauksbee, not a single electrical experimenter of note, either in England or the rest of Europe, appeared until Gray in London communicated his first paper to the Royal Society. This was in 1720, about seven years after Hauksbee's death, but only a year after the publication of his second edition.

Again attention was diverted. Gray's

work gained the admiration of Du Fay in France. Then came Abbé Nollet and Franklin, who aroused unprecedented public enthusiasm by wonderful new discoveries in electricity. More powerful static machines were constructed, the Leyden jar was invented, and wire conductors enabled demonstrators to produce amazing effects at a distance. Teachers in schools and colleges found themselves surprisingly popular. The public literally crowded the students out of their seats in lecture rooms. Hauksbee was forgotten, until noticed by Priestley. Priestley's work went through three editions. But the rapid and vast ramification of electrical progress soon left all these early publications undisturbed on library shelves.

While it is impossible to survey the endless literature of electricity that has since arisen, yet a search in those volumes most likely to contain references to Hauksbee, such as histories and textbooks, reveals only infrequent mention of this early investigator. His work is highly praised but his experiments of rendering opaque bodies transparent remains strangely unnoticed, except by Priestley, The Two Gentlemen of Philadelphia, and Thomson in his History of the Royal Society. Thomson allots considerable space to Hauksbee's demonstrations but his account of the experiments with sealing-wax and pitch is the briefest possible. He writes:

"Mr. Hauksbee next lined a globe with sealing-wax and found that when exhausted and rubbed, it becomes luminous within. This globe was found to attract even when exhausted (Phil. Trans. 1708. Vol. xxxvi, p. 219). This experiment was repeated with some alterations; one-half of the inside of the globe was lined by pitch. When the globe was exhausted

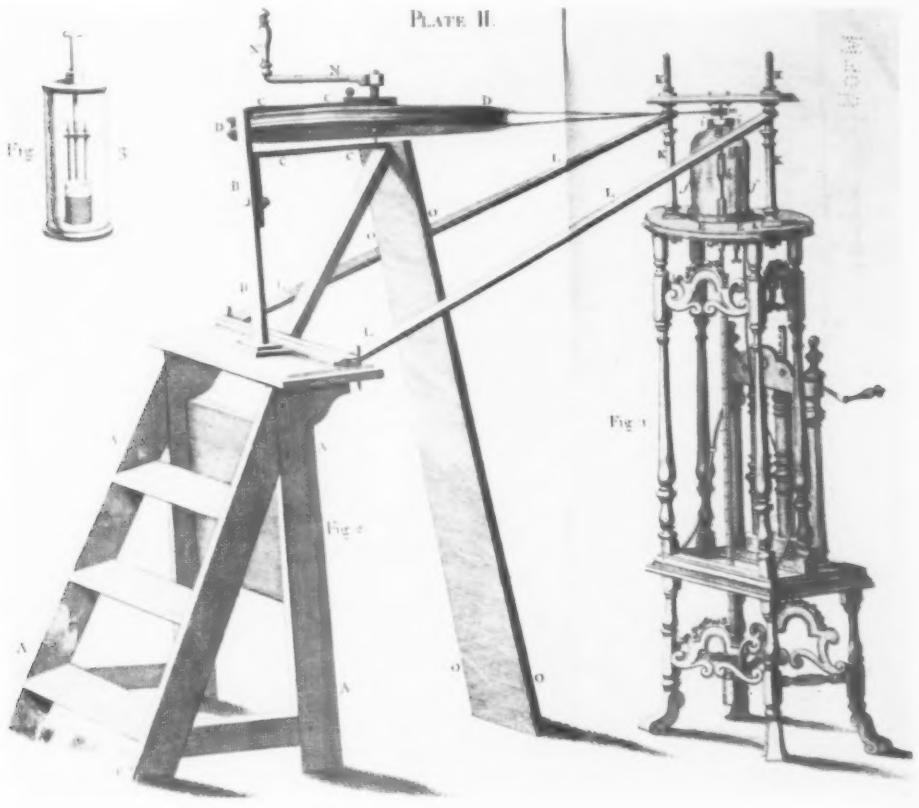


FIG. 6. Hauksbee's air-pump, still in possession of the Royal Society, showing also device for rotating the electrical machine within bell-jar. (From Physico-Mechanical Experiments. First edition.)

and the pitched part rubbed, the hand was seen luminous through the pitch (Phil. Trans. 1709, vol. xxvi, p. 391). If sulphur or wax be substituted for pitch, the experiment succeeds equally well (Phil. Trans. 1709, vol. xxvi, p. 439)."

In Weld's History of the Royal Society, in two volumes (1848), there is no mention of these experiments or of Hauksbee, except for his name in the list of Fellows. This is not surprising because Weld is chiefly concerned with the personal history of the great men of the Society and of pictures of the times in which they lived.

s'Gravesande's "Natural Philosophy," already noted, was first printed soon after the translation of Hauksbee's second edition, and could be expected to give a contemporary view of Hauksbee's contributions. While Hauksbee's name is not mentioned, many of his experiments are detailed as work done in England, and four of his illustrations copied,—the only electrical illustrations to be discovered in this great work. But nowhere in s'Gravesande do we find any allusion to the transparency of opaque bodies under electrical conditions.

It is more surprising to find only the slightest mention of Hauksbee in "A Complete Treatise on Electricity in Theory and Practice" with Original Experiments by Tiberius Cavallo, F.R.S. in two volumes (1786). This work was printed in English in London where Hauksbee lived and worked as a fellow member of the Society. Cavallo says: "As for the electric light in vacuo, numerous observations concerning its diffusibility and various shades of its colors in a moderate degree of exhaustion have been made with sufficient accuracy by Mr. Hauksbee, Mr. Dufay, Abbé Nollet, F. Beccaria, and others who likewise observed that the vacuum was a conductor of electricity." (Vol. II, p. 91, 3d edition.)

We are at loss to understand why the announcement by Hauksbee, that the hand could be seen through an opaque body did not excite more interest and comment among his own contemporaries and those of the following generation. In those times no one could have disputed his conclusions.

Park Benjamin in his masterly work, "The Intellectual Rise in Electricity" (1895) devotes twelve pages to Hauksbee's book and says "It was a brilliant piece of work and probably the first thoroughly scientific investigation of electrical phenomena." But Benjamin nowhere mentions any experiment concerning the transparency of sealing-wax and pitch.

No exhaustive recital of authorities is intended, but we may make one other reference. In the very excellent little volume, "Roentgenology," by G. W. C. Kaye, O.B.E., M.A., D.Sc., F.Inst., P., Head of the National Physical Laboratory, and a distinguished English physicist, we find an appreciative account of Hauksbee's work, but no mention or hint of "a méthod of rendering opaque bodies transparent." Kaye relates interestingly: "His [Hauksbee's] beautiful two cylinder vacuum pump is happily still in the possession of the Royal Society. It was carefully overhauled in 1926 and although over two hundred years old is still capable of pumping down to about one inch of mercury." Kaye ends his remarks about Hauksbee with "Fig. 12, copy of announcement about Hauksbee's air pumps." This is a reproduction of an

"Advertisement.

'Air-Pumps, or Engines for exhausting Air from proper vessels

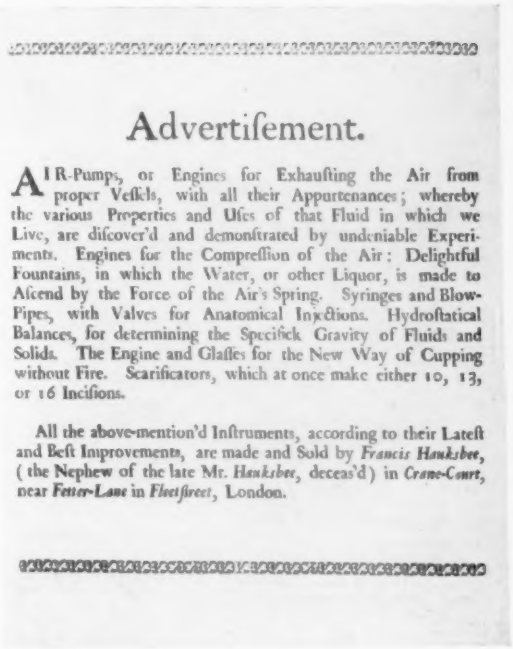
* * * * *

'All the above mention'd Instruments, according to their Latest and Best Improvements, are made and sold by Francis Hauksbee, (the Nephew of the late Mr. Hauksbee, deceas'd) in Crane-Court, near Fetter-Lane in Fleet street, London."

Reference to Thomson's History of the Royal Society shows that there are two Hauksbees, both named Francis, and both closely associated with the Royal Society. In the Dictionary of National Biography we find them distinguished as elder and younger. The younger is there referred to as probably the son of the elder Francis. But in the "Advertisement" quoted by Kaye,

we see that the relationship is that of nephew. It is clear that this "Advertisement" is not the work of Francis Hauksbee who wrote "Physico-Mechanical Experiments" and thought he saw his hand through opaque sealing-wax.

This nephew, Francis Hauksbee, served thirty-nine years as Clerk of the Royal Society and was elected to this office in 1723, ten years after the death of his illustrious uncle. He was given a yearly salary of "50 l" and was "lodg'd and found." A clerk could not be an F.R.S., or married. He must be a master of French and Latin as well as English, and be "adept in Mathematic and Experimental Philosophy." Clerk Hauksbee wrote a book about "electricity of bodies," "vitrous phosphori" and an "electrical machine to revolve a sphere of glass with air exhausted," and the "effects of electricity on strings of yarn." This sounds like a second serving of Hauksbee the elder. A further source of confusion possibly may lie in the fact that both Francis Hauksbees dedicated books to Presi-

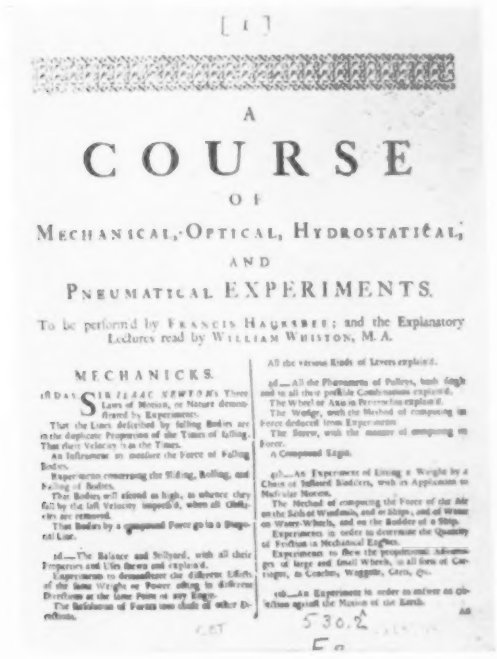


Advertiſement.

AIR-Pumps, or Engines for Exhauſting the Air from proper Veſſels, with all their Appurtenances; whereby the various Properties and Uſes of that Fluid in which we Live, are diſcover'd and demonſtrated by undeniable Experiments. Engines for the Compreſſion of the Air: Delightful Fountains, in which the Water, or other Liquor, is made to Aſcend by the Force of the Air's Spring. Syringes and Blow-Pipes, with Valves for Anatomical Injections. Hydroſtatical Balances, for determining the Specifick Gravity of Fluids and Solids. The Engine and Glaſſes for the New Way of Cupping without Fire. Scarificators, which at once make either 10, 13, or 16 Inciſions.

All the above-mention'd Inſtruments, according to their Lateſt and Beſt Improvements, are made and Sold by *Francis Hauksbee*, (the Nephew of the late Mr. *Hauksbee*, deceas'd) in *Crane-Court*, near *Fetter-Lane* in *Fleetſtreet*, London.

FIG. 8. Page from "A Course of Mechanical, Optical, Hydrostatical and Pneumatic Experiments," by Francis Hauksbee, the younger, and William Whiston, M.A. (From the John Crerar Library, Chicago.)



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A

COURSE

OF

MECHANICAL, OPTICAL, HYDROSTATICAL,

AND

PNEUMATICAL EXPERIMENTS.

To be performed by FRANCIS HAUKSBEE; and the Explanatory Lectures read by WILLIAM WHISTON, M.A.

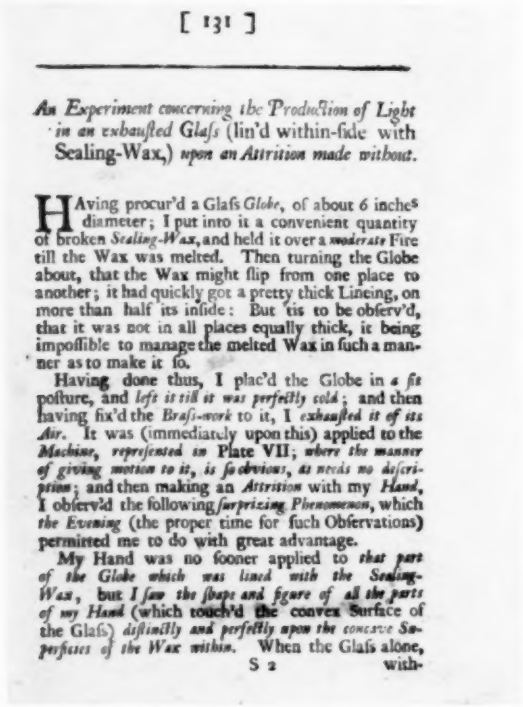
MECHANICKS.

FIG. 7. First page of book by Francis Hauksbee, the younger. No date can be found in this copy. (From the John Crerar Library, Chicago.)

dents of the Royal Society, the elder to Lord Somers, the younger to Dr. Hans Sloan. The younger Hauksbee wrote at least three books, was probably more highly educated than his uncle, and lived for years in an atmosphere of experiment and discovery; yet he does not appear to have added a single new fact to human knowledge. The elder wrote one book which by contrast is a testimonial to those qualities of mind that distinguish a thinker and investigator from one merely learned.

This book of Hauksbee the elder has become exceedingly rare. The Library of the University of Michigan possesses a copy each of the first and second editions, with text and illustrations perfectly preserved. Very few readers will ever have the opportunity of seeing Hauksbee in the original. Therefore, it may be permissible to quote, nearly in full, the chapters on rendering sealing-wax and pitch transparent. We will omit those sections dealing with what we

now know to have been electrostatic attraction, but will retain the capitalization and italics of the original which may be seen in the photographic copy of the first pages of this experiment.*



[131]

An Experiment concerning the Production of Light in an exhauſted Glaſs (lin'd within-ſide with Sealing-Wax,) *upon an Attrition made without.*

HAving procur'd a Glaſs *Globe*, of about 6 inches diameter; I put into it a convenient quantity of broken *Sealing-Wax*, and held it over a *moderate* Fire till the Wax was melted. Then turning the Globe about, that the Wax might ſlip from one place to another; it had quickly got a pretty thick Lineing, on more than half its inſide: But 'tis to be obſerv'd, that it was not in all places equally thick, it being impoſſible to manage the melted Wax in ſuch a manner as to make it ſo.

Having done thus, I plac'd the Globe in *a fit* poſture, and *left it till it was perfectly cold*; and then having fix'd the *Braſs-work* to it, I *exhauſted it of its Air*. It was (immediately upon this) applied to the *Machine, repreſented in* Plate VII; *where the manner of giving motion to it, is ſo obvious, as needs no deſcription*; and then making an *Attrition* with my *Hand*, I obſerv'd the following *ſurprizing Phenomenon*, which *the Evening* (the proper time for ſuch Obſervations) permitted me to do with great advantage.

My Hand was no ſooner applied to *that part of the Globe which was lined with the Sealing-Wax*, but *I ſaw the ſhape and figure of all the parts of my Hand* (which touch'd the convex Surface of the Glaſs) *diſtinctly and perfectly upon the concave Superficies of the Wax within*. When the Glaſs alone,

S 2 with-

FIG. 9. Page from first edition of Hauksbee's Physico-Mechanical Experiments, describing the experiment of seeing his hand through a layer of opaque sealing-wax.

"*An Experiment concerning the Production of Light in an exhausted Glass* (lin'd within-side with Sealing-Wax,) *upon an Attrition made without.*

"Having procur'd a Glass *Globe*, of about 6 inches diameter; I put into it a convenient quantity of broken *Sealing-Wax*, and held it over a *moderate* Fire till the Wax was melted. Then turning the Globe about, that the Wax might slip from one place to another; it had quickly got a pretty thick Lineing, on more than half its inside: But 'tis to be observ'd, that it was not in all places equally thick, it being impossible to manage the melted Wax in such a manner as to make it so.

"Having done thus, I plac'd the Globe in *a fit* posture, and *left it till it was perfectly cold;* and then having fix'd the *Brasswork* to it, I *exhausted it of its Air*. It was (immediately upon this) applied to the *Machine, represented in* Plate VII; *where the manner of giving motion to it, is so obvious, as needs no description;* and then making an *Attrition* with my *Hand*, I observ'd the following *surprizing Phenomenon*, which *the Evening* (the proper time for such Observations) permitted me to do with great advantage.

"My Hand was no sooner applied to *that part of the Globe which was lined with the Sealing-Wax*, but I *saw the shape and figure of all the parts of my Hand* (which touch'd the convex Surface of the Glass) *distinctly and perfectly upon the concave Superficies of the Wax within*. When the Glass alone without any such lining on the inside, is made use of; 'tis obvious to any one (who has seen or does but consider the Experiment) how plainly a Hand must be seen, which is plased on the convex Surface of a Globe all over enlightened with a strong-flashing Light. And perhaps it may seem strange, if I should say, that *the Appearance was now as plain and visible as then, notwithstanding the interposition of the thick body of wax*. 'T was as if there had been only pure Glass, and no Wax in the way; or as if the Glass had been away, and the Wax were transparent. This *Lining*, where it was spread the *thinnest*, would but just allow the Light of a Candle through it *in the dark*. But in some places, it was at least 1/8 of an inch thick. And yet even in those parts, *the Light and Figure were as distinguishable* as any where else. Nay, tho' some parts of the Sealing-Wax did not adhere so close to the Glass as others, *yet the Light appear'd on these, just as on the rest*. This Light produc'd, was *not discernible at all thro' the body of the Wax*, but was to be seen by looking thro' the other parts, where the Glass was free and transparent. The *Colour*, and other Properties of it, resembled those of the *Lights produc'd from pure Glass;* except in this one Instance, *That upon the admission of a small quantity of Air into the Globe, the Light wholly disappear'd in that part cover'd with the Sealing Wax*, and not in the other.

* * * * *

"So that in the Course of this Experiment, there are these following things to be taken notice of.

* Dr. Edward H. Skinner of Kansas City, Mo., found a copy of Physico-Mechanical Experiments, by F. Hauksbee, F.R.S., first edition, 1709, in the library of the New York Academy of Medicine.

"First, *A distinct and lively representation of the Shape and Form of an Object, upon a solid opake Body, to which that Object was not immediately applied; and this by the Light produc'd upon the Attrition of another Body (solid, tho' not opake,) to which that Object was immediately applied.*

"A Man would have been thought the Author of a very strange *Paradox*, that should have asserted this, and at the same time conceal'd the Experiment; which shews how and which way 'twas done.

"Or, should it have been propos'd by way of *Problem*, thus: *To represent the Figure of an Object (plac'd behind an opake Body) upon the contrary side of the opake Body; and this without the help of Optick Glasses, or any foreign adventitious Lights;* perhaps the Solution might have been thought impossible; or, it may be, the very Terms of the Problem itself, absurd and contradictory.

"For, the Body on which the Figure is to be seen, must be an *opake* one, (by the Hypothesis;) and the Object itself plac'd on the contrary side to that which it is seen on; So that either the Light must *be transmitted* thro' this Body, and then *'tis not opake*, which is contrary to the Hypothesis; or else the Light must *not be transmitted*, and then *no Figure could be seen;* for all distributions of Light by *Optical Artificies*, are excluded by the first Supposition.

"But we see, this is not only possible, but also plain Matter of Fact.

From whence, I think, it may be useful to observe, *That many odd Effects and Appearances, which we may argue very Plausibly to ourselves, against the possibility of; and seem to find downright Absurdities and Contractions in; may yet be brought about by the genuine Forces of Nature, acting in convenient circumstances, upon proper and suitable Bodies.*

And from hence; That we do not, upon such occasions, proceed to conclude too peremptorily, what may or may not be done; and think, that every Difficulty or *Apparent* Impossibility to us, is a *Real* one to nature itself.

"Secondly, *The uniform Clarity and Perspicuity of the Figure represented, thro' all the parts of the opake Body, (viz. the Wax,) on which it was seen, being as visible in the thickest and grossest, as in the finest and thinnest parts of it; and on those which lay out farther from the Glass, as on those which adher'd more closely to it.*

"Thirdly, *A total Disappearance of the Light in all that part cover'd with the Wax, upon the admission of a small quantity of Air; and its Continuance in the other parts of the Glass* at the same time.

"Both these last-recited Heads do also furnish something that looks pretty strange.

"Here's a figure transmitted thro' the most dense and compact parts of an opake Body, with the same facility and advantage to the Eye, that it is thro' those which should seem the most easily pervious to the radiant Matter which is to form the Representation.

"Again: Here's a *notable Distinction observable in the Lights produc'd.* They were such, that one and the same Cause *destroy'd* the one, and *left the other untouch'd.* The air swept away all which arose from the *parts lin'd with the wax;* whilst the other regions of the glass preserv'd their light without any diminution.

* * * * *

"These things thus observ'd; we may now reason a little upon 'em, in the *modest way of Enquiries.*

"1. *May not one Body attract* (and as it were imbibe) *the* Effluvia of another contiguous Body; especially when Motion and Warmth have made an easie passage for such Effluvia into the Interstices of that Body, whose attractive Power tends to fetch them thither?

"2. *Might not* (therefore) *the Sealing Wax, by vertue of that Law, incorporate with itself the Luminous Effluvia emitted from the contiguous Glass?* Glass gives a free passage to the Effluvia of Sealing Wax: May not Sealing-wax (on the other side) as freely admit the Effluvia of Glass?

"3. Supposing the Body of the Sealing-wax thus charg'd and replenished with the Luminous Effluvia of the glass, *Would it not in that state appear Luminous itself?* Do not all Bodies that shine, do so by vertue of Lucid Matter lodg'd in 'em; and, in some degree, more or less forcibly darted from 'em? Why should not Wax, every where replete with shining Corpuscles, appear shining; as well as Wood charg'd with fiery parts, gives us the sensation of a burning Coal; or *Smoke thoroughly heated*, that of a *lively Flame?*

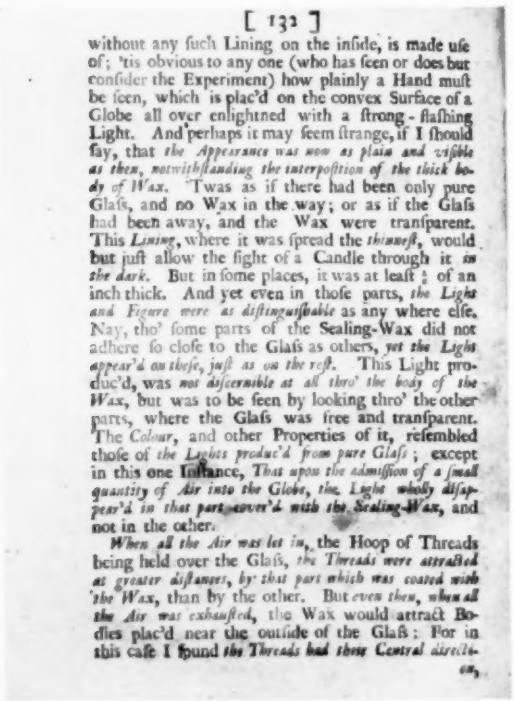
"4. *What is it to be pellucid, but to* transmit *Light* receiv'd? *And does not the Wax thus transmit the Luminous Matter, attracted and imbib'd from the Glass?*

"5. *Has not the Wax* (therefore) *in this state, a sort of Transparency?* I say *in this state:* For the property is limited to the present Cir-

cumstances of these Bodies concern'd in the Experiment?

"During the Attrition, there is an Eruption of Luminous Effluvia from the body of the Glass.

"Does not the Attraction take place, *as soon as the Matter to be attracted is furnish'd* by the



[132]

without any ſuch Lining on the inſide, is made uſe of; 'tis obvious to any one (who has ſeen or does but conſider the Experiment) how plainly a Hand muſt be ſeen, which is plac'd on the convex Surface of a Globe all over enlightned with a ſtrong-flaſhing Light. And perhaps it may ſeem ſtrange, if I ſhould ſay, that *the Appearance was now as plain and viſible as then, notwithſtanding the interpoſition of the thick body of Wax.* 'Twas as if there had been only pure Glaſs, and no Wax in the way; or as if the Glaſs had been away, and the Wax were tranſparent. This *Lining*, where it was ſpread the *thinneſt*, would but juſt allow the ſight of a Candle through it *in the dark*. But in ſome places, it was at leaſt ¼ of an inch thick. And yet even in thoſe parts, *the Light and Figure were as diſtinguiſhable* as any where elſe. Nay, tho' ſome parts of the Sealing-Wax did not adhere ſo cloſe to the Glaſs as others, *yet the Light appear'd on theſe, juſt as on the reſt.* This Light produc'd, was *not diſcernible at all thro' the body of the Wax*, but was to be ſeen by looking thro' the other parts, where the Glaſs was free and tranſparent. The *Colour*, and other Properties of it, reſembled thoſe of *the Lights produc'd from pure Glaſs*; except in this one Inſtance, *That upon the admiſſion of a ſmall quantity of Air into the Globe, the Light wholly diſappear'd in that part cover'd with the Sealing-Wax*, and not in the other.

When all the Air was let in, the Hoop of Threads being held over the Glaſs, *the Threads were attracted at greater diſtances, by that part which was coated with the Wax*, than by the other. But *even then, when all the Air was exhauſted*, the Wax would attract Bodies plac'd near the outſide of the Glaſs: For in this caſe I found *the Threads had their Central directi-*

on,

FIG. 10. Page from first edition of Hauksbee's Physico-Mechanical Experiments continuing the experiment of seeing his hand through a layer of opaque sealing-wax.

contiguous *Glass?* Is not the Wax saturated with Light as soon as the Attraction commences? And when the Wax is saturated with Light, does it not *then appear luminous?* (that is, does it not communicate some parts of the *Light receiv'd*, to the circumjacent Medium?)

"6. Since therefore the Sealing-Wax in this state, is not to be consider'd purely as an *opake Body*, which opposes the Transmission of Light, (*as it really is in all other Circumstances,*) but as a Body every where *pervious to the Lucid Matter* emitted from the neighbouring Glass, *May we not from hence conceive, how the Figure of an Object plac'd on the one side, may be represented on the contrary side thereof*, (namely, that side which is turn'd towards the Eye of the Spectator?) Why should I not as well see my Hand plac'd on the Glass, whilst the Wax is *thus open to the Luminous Effluvia;* as see it when I place it behind any ordinary transparent Body whatsoever?

"In a word, 'This plain matter of Fact, *that the Figure of the Hand is seen on the contrary side of the Wax.* And 'tis demonstrable from the very Circumstances of the Experiment, that that *Figure is not form'd there by any of the common ways of picturing Objects by Reflected or Refracted Light.*

"The Figure therefore is *transmitted thro' the Body of the Sealing-Wax.* But no *Species* or Picture can be transmitted thro' an opake Body while it continues to be Opake; that is while it continues *impervious to the Rays of Light.* Therefore the Wax must, *at that time*, be in the *contrary state;* that is, *pervious* to the Luminous Matter. This Luminous Matter is originally emitted from the Glass in the Act of Attrition; but how it should pass from thence into the the body of the Wax, without an attractive force bringing it thither, I cannot (at present) tell how to conceive.

"7. *Qu.* Whether the Figure was not as *distinctly form'd* on the thickest, as on *the thinnest parts of the Wax, upon account of* the Quantity of Luminous Effluvia *every where attracted in proportion to the quantity of attracting Matter?* And whether, it was not upon account of the very small (*comparative*) difference between the *distances of the farthest and nearest parts of the Wax, with respect to the Glass; that the Luminous Matter was pretty equally drawn to both*, and so the appearance became (to Sense) *equally distinct on both?* Or that the vibratory motion of the Effluvia at their eruption from the Glass, might bring them as well within the attractive Sphere of the remotest, as the nearest parts of the Wax?

"8. *Is not the more strong and vigorous Attraction from that part of the Glass lin'd with the Wax, caus'd by the* united attractive Forces *of the* Glass *and* Wax?"

There are more experiments along this line to follow but we may, in passing, be arrested by the fact that Hauksbee, in this explanation of his experiment, originated the term and the idea of "Radiant Matter." Later Faraday made use of this term and inspired Crookes whose classical experiments with the electrically excited vacuum

tube were for the avowed purpose of demonstrating "Radiant Matter." His lecture in 1879 before the British Association for the Advancement of Science was entitled "Radiant Matter." This lecture opens as follows:

"To throw light on the title of this lecture I must go back more than sixty years—to 1816. Faraday, then a mere student and ardent experimentalist, was 24 years old, and at this early period in his career he delivered a series of lectures on the General Properties of Matter, and one of them bore the remarkable title, 'On Radiant Matter.'"

Crookes tubes were advertised commercially as "Radiant Matter Tubes." And we must remember that it was a Crookes tube which Roentgen was using when he discovered the x-ray.

Crookes' conception of "radiant matter" was that of a fourth state of matter. Solid, liquid, gaseous;— what was the fourth state? According to Crookes it was a gas so rarefied as to be but little below a vacuum. He says, "Matter in the fourth state is the ultimate result of gaseous expansion." But Crookes failed to establish this hypothesis. His was another fruitful error in research. Matter in "an ultra-gaseous state" is still a gas. Hauksbee's conception was actually closer to a fourth state of matter than Crookes'. His "radiant matter" (or "luminous effluvia," or "lucid matter" or "luminous matter") was something akin to light but so subtle that it could pass through substances opaque to ordinary light. This supposition is not inconsistent with the quantum theory of modern physics. He was, of course, under the influence of Newton's corpuscular theory of light.

However, in a later experiment Hauksbee reverts to the theory that sealing-wax and pitch change in physical character under conditions of a vacuum and electrical excitation, so that they become temporarily transparent. This experiment is found in the second edition of "Physico-Mechanical Experiments" which contains a "Supplement" with this foreword:

"The following Experiments being made by Mr. Hauksbee after the Publication of the First edition of this Book, and not rang'd by him under any proper Section before his

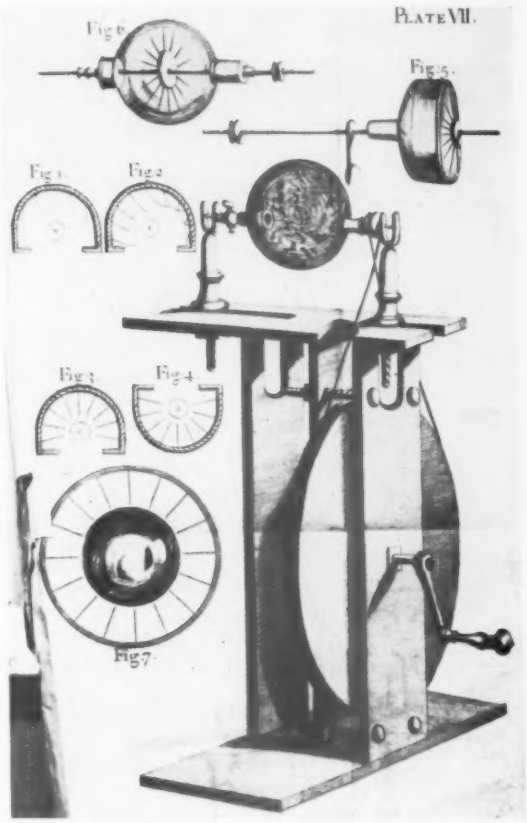


FIG. 11. Hauksbee's vacuum tube or globe with rotating table; also hoops with strings of yarn for use without and within the globe. This apparatus was used to see the hand through sealing-wax. (From Physico-Mechanical Experiments. First edition.)

Death; we have here printed them just in the Order he deliver'd them to the Royal Society."

Twenty-four experiments are numbered, covering a considerable range of physics. Five only are electrical. His results regarding the transparency of opaque bodies are now differently interpreted, as may be seen from the following

"Experiment VIII.

An Account of an Experiment, showing that an Object may become visible through such an

Opaque Body as Pitch in the Dark, while it is under the Circumstances of Attrition and a Vacuum."

* * * * *

"To conclude: This, and the forementiond Experiment of the Sealing-Wax, plainly discover a transparent Quality in some Bodies (we call Opaque) under such and such Circumstances: Bodies which are really Opaque, have hitherto been thought to continue always so. It was never so much as suspected, that they could exchange that Quality for the contrary one, and then come back from that contrary one to their old State again: That they could pass from Opaque to Pellucid, and from Pellucid to Opaque; at one time admit, and at another time oppose the Passage of Light; And all this by a meer Change of external Circumstances. This Property, I say, is as new as 'tis real and surprizing: And the bare Consideration of so very unlikely and unexpected a thing, may be a ground of Encouragement to hope, that some other odd Properties of Bodies, by some lucky Trials, may hereafter (as this has done) surprize us with a Discovery of themselves."

The roentgenologist will find something suggestive in this last of his electrical experiments:

"Experiment XIV.

An account of an Experiment concerning an Endeavor to produce Light *through a* Metallick *Body, under the Circumstances* of a Vacuum *and* Attrition.

It may be remembered, what success I had in producing Light through Bodies, such as Sealing-Wax, Pitch and common Sulphur; which gave me some probability, that under the same Circumstances I might likewise make some such Discovery thro' a Mettalick Body."

He then makes use of a globe half glass and half brass. He says:

"I applied my Hand to the Brass Hemisphere in Motion, but no light could be discovered within."

He tries many variations of the experiment and after the last trial states

"But this, and whatever else I then did try, was to no purpose."

In his preceding experiment with a lining of sulphur instead of pitch he ends with these words suggestive of Francis Bacon:

"The Powers of Nature are not to be determined beforehand by *Demonstration* but to be search'd out by *Observation* and *Experiment.* And as these Trials have open'd the way to *something that looks with a very promising Aspect:* So we hope by degrees to persue them with some good Success."

These concluded Hauksbee's electrical experiments. Ten experiments on other subjects follow before death put an end to his labors. His work was safely recorded in the archives of the Royal Society. His book covers an extraordinary range and makes him an outstanding exponent of the experimental physics of his age. His papers on the development of the electrically excited vacuum tube are the most original and best known of his works. Like Aladdin he had rubbed his lamp and genii had appeared, matching in power and obedience those of the Arabian Nights; but many years had yet to pass before anyone could recognize them and find the magic formula of command.

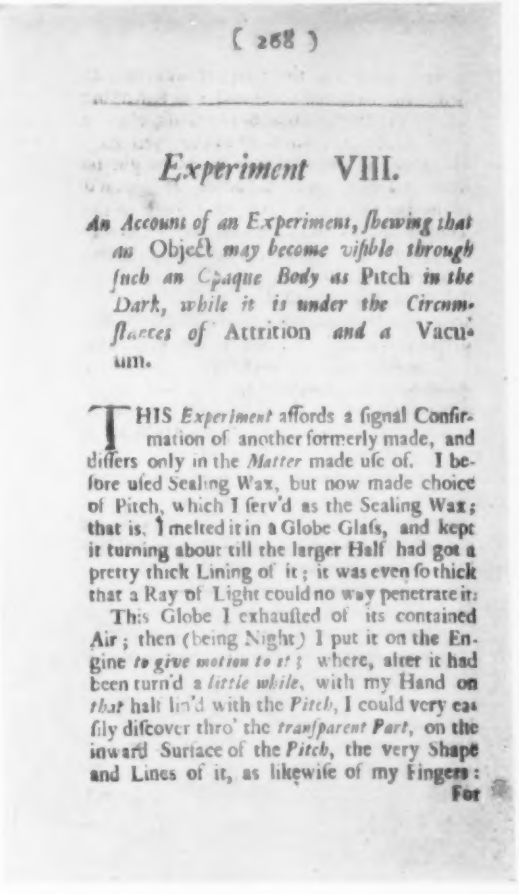
We raise our eyes from these early records and wonder what Hauksbee actually saw. To the average reader, a vacuum tube excited by electricity suggests x-rays or some form of emanation of similar properties. He might ask, could the hand making friction on glass be a source of such emanations and could the concave surface of sealing-wax, or a layer of ionized air, take the place of a fluorescent screen? We are reminded that friction on glass and on sealing-wax yields vitreous and resinous electricity —our primary source of distinction between positive and negative charges. To Hauksbee's mind the light which outlined his hand could not appear on the opposite side of a layer of sealing-wax or pitch unless that light had passed through these opaque substances. He had no conception of electrostatic induction or the ionization of gases, although he had demonstrated

both these phenomena in his experiments with electricity and vacuum tubes.

Thinking that it would be interesting to see again what Hauksbee saw and to have the explanation of a trained physicist, I laid the whole matter before Dr. J. W. Hornbeck, Professor of Physics in Kalamazoo College and asked his cooperation in repeating these experiments. Professor Hornbeck was frankly surprised that this work, of such historical interest, should have been so long neglected and lost from sight. He also searched the literature for further mention of these experiments with negative results.

It was his immediate hypothesis that the phenomenon was due to an electrostatic effect on the residual gas-layer on the inner surface of glass and wax, and not to a rendered transparency of the wax, as Hauksbee thought. However, he and his assistants proceeded to set up the experiment as Hauksbee described, except that a motor-driven machine was used to rotate the tube. Tubes were blown, in the Department of Mechanics of the College, to correspond in size and shape with that of Hauksbee. The half of the globe which was coated with sealing-wax was located about one axis so that its image could be viewed without interruption through the uncoated glass portion.

It was a rather tense and expectant moment when the dry hand was applied to this rotating tube in the dark. The vacuum was low, to correspond with the known capacity of Hauksbee's air-pump. In a few seconds a glow could be seen in the tube. It brightened, and the outline of the hand and fingers, which were held on the side opposite to the eyes, could be seen through the clear glass from this light within the globe. The surface of the hand in contact with the glass became luminous, showing the creases and lines of the skin on fingers and palm. There was no penetration of the hand as with the roentgen ray. When the hand was passed behind the layer of sealing-wax, it was seen exactly the same as when held over the uncoated portion of the globe. There was no difference. Hauksbee's description, disentangled from his theories and explanations, was accurate in every detail. The experiment today can be described in his own words. It is a tribute both to Hauksbee's careful description, and to Professor Hornbeck's skill as an experimenter, that this repetition of a two-hundred-year-old experiment succeeded so perfectly. This was on the evening of December 12, 1932.



(268)

Experiment VIII.

An Account of an Experiment, ſhewing that an Object *may become viſible through ſuch an Opaque Body as* Pitch *in the Dark, while it is under the Circumſtances of* Attrition *and a* Vacuum.

THIS *Experiment* affords a ſignal Confirmation of another formerly made, and differs only in the *Matter* made uſe of. I before uſed Sealing Wax, but now made choice of Pitch, which I ſerv'd as the Sealing Wax; that is, I melted it in a Globe Glaſs, and kept it turning about till the larger Half had got a pretty thick Lining of it; it was even ſo thick that a Ray of Light could no way penetrate it: This Globe I exhauſted of its contained Air; then (being Night) I put it on the Engine *to give motion to it*; where, after it had been turn'd a *little while*, with my Hand on *that* half lin'd with the *Pitch*, I could very eaſily diſcover thro' the *tranſparent Part*, on the inward Surface of the *Pitch*, the very Shape and Lines of it, as likewiſe of my Fingers: For

Fig. 12. Page from Supplement of second edition of Hauksbee's Physico-Mechanical Experiments, describing the experiment of seeing his hand through an opaque layer of pitch.

Professor Hornbeck then proceeded with variations of the experiment in order to study the phenomenon systematically and to test out his hypothesis that the residual

layer of air within the tube, next to the inner surface of both glass and sealing-wax, was made luminous by the friction of those parts of the hand in actual contact with the outside of the glass. This luminosity followed accurately the points of contact, no matter what was the substance or body exerting the friction. The sealing-wax, pitch, or sulphur simply provided a suitable surface like the glass for the exhibition of this phenomenon. The same effect, but less spectacular, was observed when the vacuum tube was made luminous by a high frequency electrode, and the hand applied to the surface of the quiescent tube. The luminous image of the hand is again seen as well on the inner surface of the sealing-wax as through the glass, although there was no motion and no friction of the hand. Whether or not the experimenter were grounded made no perceptible change in the experiments. The effect fades with too high or too low a vacuum. With a lower vacuum the luminosity of the contained air changes and streamers dart from side to side when the tube is charged from the friction of the hand as well as when excited by the high frequency electrode.

Hauksbee failed to get the effect of transparency when his tube was coated with flowers of sulphur, although with common sulphur he succeeded as with pitch. He also used a globe, half glass and half metal, but could not see his hand when it was placed behind the metal. Professor Hornbeck could find no difference in effect, between flowers of sulphur and sealing-wax, but confirmed Hauksbee's findings when metal was used. A tube was half-coated on the inside with tinfoil and exhausted as were the others. But no image of any kind could be seen when the hand was passed behind this metallic coating, although through the glass portion of the tube, it was luminous and visible as before.

The explanation of these different phenomena is given by Prof. Hornbeck in the following statement which he has very kindly furnished me at my request.

EXPLANATION OF THE HAUKSBEE PHENOMENON

By Prof. J. W. Hornbeck
Dept. of Physics, Kalamazoo College

It is well known that the luminous discharge in gases is often quite complicated. However, recent research on the theory of energy levels has made it clear that the emission of light is associated with ionization, or at least with the "excited" state of a gas. In our experiments the main factors responsible for ionization of the residual gas are not far to seek.

Keeping in mind the fact that the rotating globe is highly charged with electricity, an abrupt change of potential occurs at the surface of contact where the hand rubs against the glass. Therefore a potential gradient is established through the glass and into the residual air next to the local area of contact. The resulting electric field, being proportional to the space-rate of change of potential, will be very strong within the glass and wax adjacent to the hand and will fade rapidly for points in the gas at any considerable distance from the hand. In other words, the lines of force of the electric field in the gas-layer will diverge as one leaves the area of contact. In such a non-uniform field one should expect ionization by collision only within a region very close to the inner surface adjacent to the hand, i.e., where the field is strongest. And this is what we observe. Any large adjustment of the residual gas pressure would naturally change the character and extent of the luminosity, due to the change in the mean free path.

Furthermore, when the vessel is lined with tinfoil, the whole metallic lining must remain an equi-potential surface simply because it is a good conductor. When such a vessel is charged by friction of the hand, the local gradient of potential, above-mentioned, is not produced and a local field does not exist in the gas. Consequently the residual gas, opposite the hand, is not ionized.

We see from the foregoing statement by Professor Hornbeck that the reason why Hauksbee saw the image of his hand through opaque sealing-wax, though not through metal, was because the residual air in his vacuum tube was ionized on the surface of the wax, though not on the metallic surface which was a perfect conductor of

the static charge. Mistaken though he was, Hauksbee's experiments in 1709, by their anticipation of Roentgen's discovery, constitute a prophetic error without a parallel in the history of science.

Francis Hauksbee is known to us only in a brief scientific career of seven years. A study of his papers shows him to have attained an outstanding position in the experimental physics of his age. We have seen that he was the first to excite a vacuum tube by an electrical machine, the first to describe the resulting phenomena of luminescence, and the first to conceive the idea that, by such a tube, "radiant Matter" could be generated, capable of penetrating material opaque to ordinary light. His mistakes were those of genius in advance of its time. Science progresses by trial and error. He has not received his full due in the history of physics or in the annals of roentgenology. The range and originality of his experiments, his powers of minute observation, his inventive and mechanical skill, the boldness and candor of his speculative reasoning, the present-day results traceable to his work, all combine to make his book one of the imperishable landmarks of scientific progress.

THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

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For Preliminary Program of American Congress of Radiology: See April Number, American Journal of Roentgenology and Radium Therapy, page 539.

Date of Meeting: September 25–30, 1933.

Place of Meeting: Palmer House, Chicago, Ill. Scientific Sessions, Scientific and Commercial Exhibits will all be held in this Hotel.

* For Officers and Standing Committees of the American Roentgen Ray Society and the American Radium Society usually carried on this page, see the April, 1933, number of the Journal.

† Combined meeting of: American Roentgen Ray Society, American Radium Society, American College of Radiology, Radiological Society of North America.

EDITORIAL

RADIODERMATITIS

IN A small proportion of the thousands of patients exposed to roentgen rays or radium for diagnosis or treatment, accidental overexposure or undue, though deliberate, exposure may lead to reactive dermatitis. In connection with treatment of malignant tumors, in particular, mild radiodermatitis is common, but by the more experienced therapeutic radiologists dermatitis to the point of ulceration is carefully avoided. As a rule, such severe tissue damage results from inexperience or accidental error. For years it has become a medical custom to designate such reaction by the expressions "x-ray burn" or "radium burn," much as one would speak of sunburn. In a way this is quite natural and proper, but certain considerations would seem to point to the greater wisdom of avoiding the use of such terms altogether, or at least of limiting their application to destructive or ulcerative lesions. An important reason is that, as a result of dreadful stories circulated among the laity, a peculiarly sinister meaning has become attached to such expressions. Unfortunately, many physicians are careless in this respect, while others unfamiliar with the action of radiation on the tissues often do not hesitate to regard as due to irradiation lesions that have nothing whatever to do with roentgen rays or radium, such as those of herpes zoster. With some the unhesitating use of these expressions is based on the self-righteous and unreasoning determination to tell the whole truth to every patient, regardless of consequences and of the mental anguish often resulting from such elementary lack of human sympathy.

To some extent every physician lives in a glass house, in the sense that he cannot always make an accurate diagnosis and that he cannot be certain that the treatment which he prescribes in a given case and at a given time will be effective. To mention one example among many, even the best surgeon may occasionally commit an error of judgment or execution which may sometimes have serious consequences for the patient. In other words, the physician as a human being is necessarily prone to error. Of course, the conscientious practitioner adopts every possible safeguard against error, but in this respect some are less meticulous than they might be or unusual circumstances in certain cases may lead to some hasty or injudicious act. At any rate, to deny that in the practice of medicine errors occur would be as ridiculous as to maintain that the earth is flat. If this quite natural tendency of human faculties occasionally to err is admitted, it behooves every physician to avoid casting stones at a fellow practitioner, if only because glass houses are so fragile.

The diagnostic and therapeutic use of roentgen rays and radium is gradually extending and will probably continue to extend for some time to come. Among the factors responsible for such extension are the increasing number of reports of favorable results in cases previously treated by other methods or in which the disease hitherto had been allowed to follow its natural course or in which only palliative relief of symptoms had been attempted; increase in our knowledge of the physical, physiological and pathological effects of irradiation and diffusion of such knowledge among a larger number of physicians, increase in the number of expert radiologists and in their individual skill, better understanding of the indications and limitations of radiotherapy, better con-

struction and greater safety of apparatus to generate roentgen rays, and greater familiarity with the usefulness of roentgen rays and radium on the part of physicians working in hospitals or engaged in private practice. However desirable and advantageous such extension may be in many respects, it is becoming apparent that, in some respects, the wider use of these valuable agents is responsible for many unfortunate accidents or incidents, or that many patients do not receive the benefit which should result from expert treatment.

One of the main reasons for this apparent anachronism, as far as roentgen rays are concerned, is that, although the number of skilled specialists has been slowly increasing, others less skilled and physicians without special training or experience in radiotherapy have been led to believe that the chief or sole requirement for this kind of treatment is electrical equipment. The progressive simplification of generating apparatus and the commercial urge to increased sales have led the manufacturers' agents to make roentgen therapy appear as simple as possible. Also, the vogue of mechanical gadgets to perform a multitude of tasks which formerly had to be done by hand has engendered in the lay public the notion that the possession of an x-ray machine necessarily implies the skill to use it for any required purpose. So much so, indeed, that many patients seem surprised to learn that the possession of apparatus to generate roentgen rays does not confer skill on the possessor and does not connote experience. The same may be said concerning the possession of radium. Many physicians, influenced by the advertisements of commercial firms or individuals, have been led to assume that treatment of various lesions with radium does not require special skill and experience, and that, given specific instructions by the advertiser, any medically trained person can give such treatment. A moment's thought should be sufficient for anyone to realize how unsound are such ideas. No one, for instance, would dare to assume that the only requirement for expert surgery is a kit of surgical instruments and that, by purchasing or renting the instruments, any physician may *ipso facto* become qualified to perform any surgical operation.

In the past and even at the present time, also, a certain proportion of roentgenologists, whose practice has consisted mainly of diagnostic roentgenology and whose income, therefore, has been derived chiefly from this source, have given scant attention to the therapeutic aspects of the subject. In spite of this lack of interest, however, they have not had the courage to limit themselves exclusively to diagnostic roentgenology, but have continued to accept cases referred for treatment, either because their position on the staff of a hospital required them to do so or because they have been unwilling to admit the deficiency. Under such circumstances, treatment has often been delegated to a technician and has not received the detailed and constant supervision which radiotherapy of high grade requires.

The foregoing factors probably account in large measure for the relative frequency of destructive radiodermatitis, even if the proportion of cases in which pronounced cutaneous reaction incidental to roentgenographic or roentgenoscopic overexposure is excluded. In many if not in most cases gross therapeutic overexposure results from accidental omission of filters when the other technical factors are based on some degree of filtration. As long as the human equation plays such a large part in radiotherapy accidents due to faulty memory or observation are bound to occur. The frequency of such accidents will diminish only as dependence on individual human faculties diminishes. But too much reliance on electrical or mechanical devices to guard against human frailty does not guarantee against accidental error. The best safeguard is detailed and expert human supervision, or a combination of electro-mechanical devices and human supervision, and this

applies to all phases of radiology, whether diagnostic or therapeutic.

If radiologists or others who employ radiations for diagnosis or for treatment could see some of the undesirable effects of overexposure or excessive irradiation, and could thus come to realize more fully the prolonged misery or disability which such unfortunate occurrences so often entail, fewer physicians would undertake radiologic procedures without adequate preparation, and a larger number of radiologists themselves would refine their methods and institute such supervision of details of procedure as to minimize to the utmost the dangerous possibilities. In many cases, unfortunately, the responsible radiologist or clinician does not see the patient when the radiodermatitic reaction is at its height or at any time during the early part of its protracted course; in fact, he may not see the patient again unless it be under the distorting light of a medicolegal action. During the interval the patient is most likely to consult some one else, a dermatologist or a general or plastic surgeon. Therefore, one of these specialists may have seen a considerable number of cases and may have acquired an extensive experience in the treatment of such lesions.

For example, in 1931 and again in 1933, the well-known plastic surgeon, Davis*, of Baltimore, wrote on this subject two articles, in which he describes many cases and the treatment by which the damaged tissues were repaired and defects were corrected. Among the cases cited by David were many in which an inflammatory or other benign condition, such as infection of the cheek, exophthalmic goiter, or tuberculous adenitis or peritonitis had been irradiated repeatedly for a long time. Here it is pertinent to mention that many radiologists have not yet learned that tumor or tolerance doses are not necessary and should not be used in dealing with inflammatory or benign conditions, and especially that, in benign as well as in neoplastic lesions, irradiation to or beyond the threshold of tissue tolerance cannot be repeated indefinitely without risk. These points apply with still greater force when the treatment is directed to a disease of the skin. Even if the dose given to each field at each course of treatment is within the limit of tolerance, it is extremely important to know when to stop treatment or when to diminish the dose. Sometimes it is not easy to resist the importunities of the patient or his referring physician. Substantial improvement having resulted from previous exposures, it is natural to expect that additional treatment should be equally effective. Here the likelihood of improvement must be weighed against the risk of repeating the treatment, and the desires of the patient or of his physician must not be allowed to warp one's judgment. Another point, often overlooked in relation to radiotherapy, is the number of roentgenograms of the same part of the body that may recently have been made by the same or by some other roentgenologist, and the interval since such roentgenograms were made. Of radiodermatitis resulting from diagnostic procedures nearly all cases can be attributed to overexposure from inadvertently prolonged roentgenoscopy (excessive total dose), from too frequent roentgenography within a given time (time limit of tissue tolerance), from unwarranted trust in certain measuring instruments the accuracy of which is not tested frequently enough, or in the veracity or reliability of assistants.

Davis justly concludes that severe radiodermatitis is much too common, that the dangers inherent in radiologic procedures should be stressed, and that the medical use of roentgen rays and radium should be restricted to qualified experts. At the present time, unfortunately, such restriction has not yet been achieved, but for the benefit of the public as well as that of the profession itself, it is high time that measures be taken to ascertain and certify the qualifications of radiologic specialists.

A. U. Desjardins

* Davis, John S. Deep roentgen-ray burns. Am. J. Roentgenol. & Rad. Therapy, 1931, *26*, 890–893.

Davis, John S. Clinical illustrations of deep roentgen-ray and radium burns. Am. J. Roentgenol. & Rad. Therapy, January, 1933, *29*, 43–78.

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this section solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

United States of America

American Roentgen Ray Society
Secretary, Dr. E. P. Pendergrass, University Hospital, Philadelphia, Pa.
Annual Meeting: Chicago, Ill., Sept. 25–30, 1933.

American College of Radiology
Secretary, Dr. Albert Soiland, 1407 S. Hope St., Los Angeles, Calif.
Annual meeting: Chicago, Ill., Sept. 25–30, 1933.

Section on Radiology, American Medical Association
Secretary, Dr. J. T Murphy, 421 Michigan St., Toledo, Ohio.
Annual meeting: Milwaukee, Wis., June 12–16, 1933.

Radiological Society of North America
Secretary, Dr. D. S. Childs, 607 Medical Arts Bldg., Syracuse, N. Y.
Annual meeting: Chicago, Ill., Sept. 25–30, 1933.

Radiological Section, Los Angeles County Medical Society
Secretary, Dr. D. R. MacColl, 2826 S. Hope St., Los Angeles, Calif.
Meets on the third Wednesday of each month at the California Hospital.

Radiological Section, Southern Medical Association
Secretary, Dr. C. H. Heacock, 20 S. Dunlap St., Memphis, Tenn.
Annual meeting: Richmond, Va., November, 1933.

Brooklyn Roentgen Ray Society
Secretary, Dr. G. W. Cramp, 921 President St., Brooklyn, N. Y.
Meets monthly on first Tuesday, October to April.

Buffalo Radiological Society
Secretary-Treasurer, Dr. Joseph S. Gian-Franceschi, 610 Niagara St., Buffalo, N. Y.
Meets second Monday of each month except during summer months, place of meeting selected by the host.

Chicago Roentgen Society
Secretary, Dr. George M. Landau, 660 Groveland Park.
Meeting second Thursday of each month October to May inclusive at Virginia Hotel.

Cincinnati Radiological Society
Secretary, Dr. H. G. Reineke, Christian R. Holmes Hospital, Cincinnati, Ohio. Meetings held monthly.

Cleveland Radiological Society
Secretary, Dr. M. A. Thomas, Medical Arts Bldg.
Meetings are held at 6:30 P.M. at the Cleveland Chamber of Commerce Club rooms on the fourth Monday of each month from October to April, inclusive.

Detroit Roentgen Ray and Radium Society
Secretary, Dr. E. R. Witwer, Harper Hospital.
Meets monthly on first Thursday from October to May, at Wayne Country Medical Society Building.

Florida Radiological Society
Secretary, Dr. W. McL. Shaw, 418 St. James Bldg., Jacksonville, Fla.
Meetings held twice a year, May and November.
Next meeting, Hollywood, Fla., May 1, 1933.

Illinois Radiological Society
Secretary, Dr. L. M. Hilt, Myers Bldg., Springfield, Ill.
Regular meetings held quarterly.

Indiana Roentgen Society
Secretary, Dr. J. N. Collins, Indianapolis, Ind.
Annual meeting each February 22 in Indianapolis.

Michigan Association of Roentgenologists
Secretary, Dr. S. W. Donaldson, St. Joseph's Mercy Hospital, Ann Arbor, Mich. Three meetings a year, Fall, Winter, and Spring. Next Meeting, University Hospital, Ann Arbor, Mich., May 27, 1933.

Milwaukee Roentgen Ray Society
Secretary, Dr. J. E. Habbe, 221 Wisconsin Ave., Milwaukee, Wis.
Meets first Friday in October, December, February and April. Place of meeting designated by the president.

Minnesota Radiological Society
Secretary, Dr. L. G. Rigler, University Hospital, Minneapolis, Minn. Next meeting, Rochester, Minn., May 22, 1933.

New England Roentgen Ray Society
Secretary, Dr. Thomas R. Healy, 370 Marlboro St., Boston, Mass.
Meets monthly on third Friday, Boston Medical Library.

New York Roentgen Society
Secretary, Dr. C. W. Schwartz, 33 E. 68th St., New York.
Meets monthly on third Monday, New York Academy of Medicine, at 8:30 P.M.

Central New York Roentgen Ray Society
Secretary, Dr. H. S. Bull, 604 Masonic Temple, Auburn, N. Y.
Three meetings a year—January, May and November.

Pennsylvania Radiological Society
Secretary, Dr. W. E. Reiley, Clearfield, Penna.
Annual Meeting, Penn-Alto Hotel, Altoona, Pa., May 24–25, 1933.

Philadelphia Roentgen Ray Society
Secretary, Dr. Karl Kornblum, 3400 Spruce St.
Meeting first Thursday of each month from October to May inclusive, at 8:15 P.M., in Thomson Hall, College of Physicians, 19 S. 22d St.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. W. W. Fray, Strong Memorial Hospital.
Meets monthly on second Thursday from October, 1932, to May, 1933 inclusive, at 7:45 at the Rochester Medical Association Building.

St. Louis Roentgen Club
Secretary, Dr. W. K. Mueller, University Club Bldg.
Meets first week of each month. Time and place of meetings designated by president.

South Carolina X-Ray Society
Secretary: Dr. R. B. Taft, 105 Rutledge Ave., Charleston, S. C.
Meets at time and place of South Carolina State Medical Association.

Texas Radiological Society
Secretary-Treasurer, Dr. C. P. Harris, Houston, Texas.
Meets annually one day preceding the meeting of the Texas State Medical Association.

University of Michigan Roentgen Ray Society
Secretary, Dr. C. C. Taylor, University Hospital, Ann Arbor, Mich.
Meets first and third Wednesday evening of the month from October to June, at 8 o'clock in the amphitheatre of the University Hospital.

* Secretaries of Societies not here listed are requested to send the necessary information to the Editor.

Virginia Roentgen Ray Club
Secretary, Dr. Wright Clarkson, 205 S. Sycamore St., Petersburg, Va.
Meets annually in October.

Cuba

Sociedad Cubana de Radiologia y Fisioterapia
Secretary, Dr. Luis Fariñas, Animas 110, Havana, Cuba.
Meets monthly in Havana.

British Empire

British Institute of Radiology Incorporated with the Röntgen Society
Meets on the third Thursday of each month, from November to June inclusive, at 8:15 P.M., at 32 Welbeck St., London, W. 1., or as advertised.

Electro-Therapeutic Section of the Royal Society of Medicine (Confined to Medical Members)
Meets on the third Friday of each month during the winter at 8:30 P.M. at the Royal Society of Medicine, 1 Wimpole St., London, W. 1.

Section of Radiology and Medical Electricity, Australasian Medical Congress
Secretary, Dr. H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

Radiological Section of the Victorian Branch of the British Medical Association
Secretary, Dr. Colin Macdonald, Lister House, 61 Collins St., Melbourne, Australia.
Meets monthly at Melbourne during the winter.

Section on Radiology, Canadian Medical Association
Secretary, Dr. A. H. Rolph, 160 St. George St., Toronto, Ont.

Radiological Section, New Zealand British Medical Association
Secretary, Dr. P. C. Fenwick, The Hospital, Christchurch. Meets annually.

Continental Europe

Belgian Society of Roentgenology
Secretary, Dr. J. Boine, Avenue des Allies, 134, Louvain, (Belgium).
Meets monthly on second Sunday at d'Egmonds Palace, Brussels, except in the summertime.

Societe de Radiologie Médicale de France
Meets monthly on second Tuesday, except during months of August and September, 12 Rue de Seine, Paris.

Société Suisse de Radiologie (Schweizerische Röntgen-Gesellschaft)
Secretary for French language, Dr. A. Grosjean, La Chaux de Fonds.
Secretary for German language, Dr. Scheurer, Molzgasse, Biel.
Meets annually in different cities.

Société Francaise d'Electrothérapie et de Radiologie Médicale
Meets monthly on fourth Tuesday, except during months of August and September, 12 Rue de Seine, Paris.

Association of German Roentgenologists and Radiologists in Czecho-Slovakia
Secretary, Dr. Walter Altschul, German University, Prague, 11/52.

Deutsche Röntgen-Gesellschaft (Gesellschaft für Röntgenkunde und Strahlenforschung)
Meets annually in April in different German cities, at least once in five year in Berlin. Meets in addition every two years with the Gesellschaft deutscher Naturforscher und Aerzte.
Permanent secretary, Professor Dr. Haenisch, Klopstockstrasse 10, Hamburg, Germany.

Dutch Society of Electrology and Roentgenology
Holds two meetings a year in Amsterdam, one in the Spring, and one in the Fall.

Societa Italiana Radiologia Medica
Secretary, Professor M. Ponzio, University of Turin, Turin.

Societatea Romana de Radiologie si Electrologie
Secretary, Dr. Oscar Meller, Str. Banul Maracine 30 Bucarest, Rumania.
Meets second Monday in every month with the exception of July and August.

All-Russian Roentgen Ray Association, Leningrad, USSR, in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson.
Meets annually.

Leningrad Roentgen Ray Society
Secretaries, Drs. S. G. Simonson and G. A. Gusterin.
Meets monthly, first Monday at 8 o'clock, State Institute of Roentgenology and Radiology, Leningrad.

Moscow Roentgen Ray Society
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky.
Meets monthly on the first Monday at 8 o'clock, the place of meeting being selected by the Society.

Polish Society of Radiology
Secretary, Dr. Jan. Kochanowski, 45 Gornoslazka St., Warsaw. Meets annually.

Warsaw Section, Polish Society of Radiology
Secretary, Dr. B. Krynski, 11 Zielna St.
Meets once a month except in the summertime.

Scandinavian Roentgen Societies
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association. Each of the following societies, with exception of the Denmark Society, meets every second month except in the summertime.

Society of Medical Radiology of Sweden
Meets in Stockholm.

Society of Medical Radiology in Norway
Meets in Oslo.

Society of Medical Radiology in Denmark
Secretary, Dr. H. Scheuermann, Copenhagen.
Meets on the second Wednesday of each month from October to July in Copenhagen, at 8 o'clock in the State Institute of Roentgenology.

Society of Medical Radiology in Finland
Meets in Helsingfors.

Vienna Society of Roentgenology
Meets first Tuesday each month, October to July.

Orient

Japan X-ray Association
c/o Orthopedic Surgery, Tokyo Imperial University.
Meets annually in April.

Kinki Roentgen-Abend Society
Director, Dr. Prof. Taiga Saito, Ogawaoike, Kyoto, Japan. Meets bi-monthly on third Sunday.

THE AMERICAN COLLEGE OF PHYSICIANS

The American College of Physicians will hold its Eighteenth Annual Clinical Session in Chicago, with headquarters at the Palmer House, April 16–20, 1934.

Announcement of these dates is made particularly with a view not only of apprising physicians generally of the meeting, but also to prevent conflicting dates with other societies that are now arranging their 1934 meetings.

Dr. George Morris Piersol, of Philadelphia, is President of the American College of Physicians, and will arrange the Program of General Sessions. Dr. James B. Herrick, Emeritus Professor of Medicine of Rush Medical College, Chicago, has been appointed General Chairman of local arrangements and will be in charge of the Program of Clinics. Mr. E. R. Loveland, Executive Secretary, 133–135 S. 36th Street, Philadelphia, Pa., is in charge of general and business arrangements, and may be addressed concerning any feature of the forthcoming Session.

MALIGNANCY IN RADIO-ACTIVE PERSONS*

To the Editor of THE LANCET

SIR,—In a recent leading article (Dec. 31st, 1932, p. 1439) you say that in 1926 Dr. Martland was the first to publish observations on this important occupational affection. For the sake of historical accuracy, I desire to call your attention to the fact that at the annual meeting of the industrial medicine and public health section of the American Medical Association held in Atlantic City in May, 1925, I presented unmistakable evidence of this fact on the basis of my own investigation which, as far as I know, was the first made public on that question.

My investigation was an original study of the facts of the disease as it appeared in a number of girls employed in the radium plant in Orange, near Newark, New Jersey. The reprint of my paper contained all the essential facts, establishing the occupational origin of this disease to which I gave the name radium (mesothorium) necrosis. But it requires to be said, as pointed out in my address, that as early as September, 1924, Dr. Theodore Blum, a dentist in New York City, in an address before the American Dental Association referred to it in an obscure footnote reading as follows:

"During January, 1924, there came under my observation a case of osteomyelitis of the mandible and maxilla, somewhat similar to phosphorus necrosis, which, however, was caused by some radio-active substance used in the manufacture of luminous dials for watches. The condition has been termed 'radium jaw.'"

This note, however, attracted no attention, and has not, as far as I know, been referred to by anyone writing on the subject.

I concluded my paper with the remark:

"In any event, however, we are dealing with an entirely new occupational affection demanding the utmost attention on the part of those who are in a position to render the necessary technical assistance, but at the same time it is a safe assumption that if the insanitary habit of wetting the brush with the lips is done away with the disease itself will probably tend to disappear, or in any event become extremely rare."

This conclusion has been fulfilled since there have been no entirely new cases in the meantime, although old cases have increased as the facts have come to public notice. I recently had a call from the first case seen by me, a young woman about 32 years of age, who is now in reasonably good health and free from all pain, suffering only from a shortened limb after the disease had settled in the pelvis.

Dr. Martland has done outstanding service in giving technical attention to the true nature of this affection, and his papers on the subject are classics in medical literature. By a fortunate coincidence his services were available to the girls since he is city physician in Newark, New Jersey.

I am, Sir, yours faithfully,

FREDERICK L. HOFFMAN

Wellesley Hills, Massachusetts, Feb. 2nd, 1933

* From *The Lancet*, Feb. 25, 1933, *1*, 441–442.

BOOK REVIEWS

Books Received Are Acknowledged under Heading: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers as space permits.

THE 1932 YEAR BOOK OF RADIOLOGY. Diagnosis, edited by Charles A. Waters, M.D., Associate in Roentgenology, Johns Hopkins University; Assistant Visiting Roentgenologist, Johns Hopkins Hospital. Therapeutics, edited by Ira I. Kaplan, B.Sc., M.D., Director Division of Cancer, Department of Hospitals, City of New York; Visiting Radiation Therapist, Bellevue Hospital. Cloth. Price, $6.00. Pp. 750, with 498 illustrations. Chicago: The Year Book Publishers, 1932.

Busy roentgenologists endeavoring to keep abreast of the times in all branches of medicine as well as their own specialty cannot hope to peruse all the literature in the numerous publications. The privilege of having the important articles selected, abstracted and arranged in one volume is therefore one that should be appreciated.

In addition to selecting the most interesting and valuable papers from our own leading radiological journals which are available to all roentgenologists, the authors have gleaned from numerous state journals and have thoroughly searched the foreign field. A rapid survey shows over seventy of these publications including those from England, Canada, Australia, New Zealand, France, Germany, Italy, Austria, Switzerland, Norway, Sweden, Spain, Russia and China.

The book is not a haphazard collection but the abstracts are carefully assembled and correlated, about equal parts of the volume being devoted to diagnosis and therapy, and each subject being grouped under the body system involved.

Among the interesting articles on the osseous system in the diagnostic section are descriptions and illustrations of Michaelis' disease, of nine different types of tumors of the scapula, numerous tumors of other bones, melorheostosis, lead poisoning, knee joint pneumography and contrast diagnosis, and many others of almost equal importance. Notable among articles on the glandular system are those on hepatosplenography, thorotrast, sialography, visualization of lymph nodes and breast roentgenography. The gastrointestinal review includes gastrophotography, the use of the pneumatic compressor, mucosal mapping, gastric neurinoma, intestinal polyposis, and amebiasis of colon.

Respiratory system abstracts deal with azygos lobes and scissuritis, actinomycosis of the lung, free fibrin bodies in the pleural space, and traumatic diaphragmatic hernia. In the cardiovascular section we find methods of cardiac mensuration, heart en cuirasse, cardiac aneurysm, kymoscopy and visualization of varicosities. Meteorism as a cause of troublesome shadows in genitourinary work, luizym preparation for pyelography and Carhart's original method for estimating kidney function are high lights in the next section. The neurological papers include interesting brain tumors and an intriguing exposition of cerebral arteriography. To complete the diagnostic portion several pages are given over to new developments in technique, medico-legal work and teaching problems.

Noteworthy features of the division of therapy are discussions of total body exposures in skin diseases, radium and radium ointment in treatment of roentgen carcinoma and late roentgen injuries, grenz-ray therapy, injuries to the eye from roentgen therapy, treatment of diseased tonsils by radon, treatment of acute mastoiditis, evaluation of technique and results of Coutard's therapeutic methods by several prominent therapists, irradiation of the barium-filled stomach for carcinoma and treatment of prostatic hypertrophy. Of considerable interest are discussions of the irradiation of the medulla oblongata in hypertension, irradiation of the suprarenals in dry gangrene of the extremities, radiation therapy of angina pectoris, epilepsy, trigeminal neuralgia, radiculitis, prostatic hypertrophy, painful heel due to gonococcal infection and roentgen-ray and radium injuries.

This greatly abbreviated list of subjects, though an incomplete résumé of the contents of the Year Book, should give one an appreciation of its store of information.

In addition to the abstracts, Waters and Kaplan have exercised the editorial privilege of

making a brief comment at the close of many articles. While the editorial opinion may not always coincide with that of the author or reader it certainly adds to the value of the work to have the opinion of leading roentgenologists to assist one's judgment in setting a value upon the assertions of the author. The policy of the editors is also to be commended in including some articles which contain little that is strictly new but which are well worth reviewing and re-emphasizing.

Minor criticisms may be made, such as the presence of inverted cuts and the incomplete subtitles in the case of some of the illustrations which are of necessity removed from the descriptive matter in the text. These are excusable in a volume hurried in publication as such a book must be.

The book is recommended to all roentgenologists and all other medical men who wish to keep informed on the newer developments in the medical world. Those who purchase the Waters and Kaplan Year Book will be well rewarded and will look forward to the privilege of obtaining a similar volume for 1933.

E. W. HALL

RÖENTGENOLOGISCHE BEOBACHTUNGEN ÜBER DIE BEWEGUNGEN DER WIRBELSÄULE. (Roentgenologic observations on the motions of the vertebral column.) (*Acta radiol.*, Suppl. XIII.) Von Sigvald N. Bakke, Stadtisches Krankenhaus "Haukeland," Bergen. Paper. Price, Swed. crowns 10.00. Pp. 75, with 24 illustrations. Stockholm: P. A. Norstedt & Söner, 1931.

A perusal of the literature shows that the conceptions on the motion of the vertebral column and its mechanics are quite divergent. The author made use of the roentgen procedure and he found that this method, contrary to what has been said by other investigators, especially Müller, may be used to advantage. The material included 24 females and 20 males between the ages of three and seventy-nine years. The roentgenograms were made with the Potter-Bucky diaphragm, at a distance of 150 cm., either in the erect but mostly in the recumbent position. The angulation of the vertebrae was then measured and the degree of flexion in both the anteroposterior and lateral views estimated. The following findings were obtained:

1. Dorsal and ventral flexion: (*a*) Cervical spine. The greatest flexibility was encountered between the fifth and sixth segments, the total value reaching 20.4° (dorsal flexion, 16.6°; ventral flexion, 3.8°). The flexibility of the entire cervical spine amounted to 80.5° (dorsal, 64.2°; ventral, 16.3°). (*b*) Thoracic spine. Here the greatest flexibility was found between the first and second segments, amounting to 9.8° (dorsal, 4.8°; ventral, 5.0°). In the rest of the segments the total flexibility amounted to an average of 5°. It must be mentioned, however, that the dorsal flexion in this part of the spine was the smallest, corresponding to only 0.1° between the fourth and fifth segments. Proceeding downwards, the dorsal flexibility increased. The flexibility of the entire thoracic spine amounted to 67.9° (dorsal, 220;°; ventral, 45.9°). (*c*) Lumbar spine. The greatest flexibility was here encountered between the fourth and fifth segments, corresponding to about 13°. Between the fifth lumbar and first sacral segment the flexibility increased to 23 to 24° (dorsal, 21 to 22°; ventral, 1 to 2°). The flexibility of the entire dorsal spine amounted to 70.6° (dorsal, 54.2°; ventral, 16.4°).

The dorsal and ventral flexibility of the entire spine amounted to 219° (dorsal, 140.4°; ventral, 78.6°). These figures compared with those of other investigators as follows: Fick, 428° (dorsal, 225°; ventral, 203°), and Weber, 334° (dorsal, 141.7°; ventral, 192.3°).

2. Lateral flexion: (*a*) Cervical spine. The greatest amount of lateral flexibility was encountered between the third and fifth segments, corresponding to 6°, the flexibility of the total cervical spine amounting to 23°. (*b*) Dorsal spine. Here the lateral flexibility is distributed quite evenly, corresponding to about 2 or 3° for each segment, so that the flexibility of the entire cervical spine gives a value of 30.6°. (*c*) Lumbar spine. The greatest flexibility in this region was found between the second and fifth segments, corresponding to 7 to 8°. The flexibility of the entire lumbar spine amounted to 24.3°.

The flexibility of the entire vertebral column amounted to 75 to 80° (the figure of Fick is 165°). All in all, the figures are quite different from those of other investigators. The author also found that, contrary to what was believed, the flexibility of the individual segments decreases or increases gradually from vertebra to vertebra, there being no inflexible segments in any part of the vertebral column.

Twenty-four figures (mostly roentgenograms) are appended illustrating the method of procedure.

T. Leucutia

Tecnica radiologica per l'esame della colonna vertebrale. (Roentgen technique of examination of the vertebral column.) By Fermo Mascherpa. Estratto dalla pubblicazione edita a cura della casa edile per le assicurazioni sociali di Milano. Anno 10.

This monograph deals, as the title indicates with roentgen technique of the examination of the spine. The fundamental principles which are discussed in the first part are the necessity: (1) of using various projections, (2) of using various positions, (3) of using various directions of the radiation beam, (4) of directing the central ray over the part to be examined, and (5) of supplementing the examination with a roentgenogram of the entire spine.

The author then describes the instrumentarium (tube stands, Potter-Bucky diaphragm, compressing cones, auxiliary apparatus, etc.), the general technique (teleroentgenography, stereoroentgenography, roentgenography without intensifying screens), and the special methods used for the different portions of the spine. These latter are arranged in a tabular form.

In summarizing, the following recommendations are made: (1) One should always use a Potter-Bucky diaphragm even in teleroentgenoggraphy; (2) the optimum distance corresponds to 1.20 meters; (3) in addition to a roentgenogram of the ensemble, films should be made of the particular portions involved with use of a compressor (according to Dyes); (4) the patient should be examined in all positions: in case of static disturbances in the erect, otherwise in the recumbent position; (5) the fundamental projections are the sagittal, lateral and oblique, but other projections should be added in special cases; (6) the softest rays should be used. In case of curvature of the spine the central ray should always be directed to the center of the curvature.

A bibliography of 90 articles is appended.

T. Leucutia

A Review of the Work of the Radium and Deep Therapy Department, 1924–1931, Christchurch Hospital, New Zealand. By P. Clennell Fenwick. Pp. 16. 1931.

This short pamphlet constitutes the Sixth Annual Report of the Radium Department of Christchurch Hospital, New Zealand. The institution owns a total of 659 mg. of radium element and is equipped with a deep roentgen therapy apparatus, permitting the treatment of all types of cancer. The number of patients during the last six years was 1,420 and is increasing yearly.

The report gives in a brief résumé the methods of treatment used in gynecological cancer, uterine fibroids, cancers of the breast, skin, buccal cavity, lip, larynx, bladder, prostate, penis and rectum, and of some non-malignant conditions. The methods, as a rule, coincide with those used in other institutions, the general principle being that every surgical operation for malignant disease should be preceded and followed by roentgen treatment in the hope that any wandering cancer cells that have escaped the limits of operation may be destroyed and thus metastasis prevented. In the concluding chapter, several accessory methods are briefly enumerated, among these the use of insulin either alone or in conjunction with radium packs, the use of sodium oleate, and the administration of morphia (1/3 gr. daily), the impression being gained that they all have certain advantages. In conclusion, the opinion is expressed that radium has earned its place as the greatest ally in the treatment of malignant disease that has ever been granted to the medical profession.

T. Leucutia

DEPARTMENT OF TECHNIQUE

Department Editor: Robert B. Taft, 105 Rutledge Ave., Charleston, S. C.

A NEW APPARATUS FOR ENCEPHALOGRAPHY*

By S. H. EPSTEIN, M.D., *and* S. S. HANFLIG, M.D.
BOSTON, MASSACHUSETTS

OUR purpose in this paper is to describe a new apparatus designed to facilitate the performance of encephalography. In a previous communication,[1] it was pointed out that the use of non-volatile anesthetics tended to mitigate the severity of the after-effects, and to make the procedure less disturbing for both the patient and the operator. It was further shown that by this method, the roentgenologist had no interference with his technique from the patient. This is of especial advantage in dealing with psychotic, disturbed, or fearful patients.

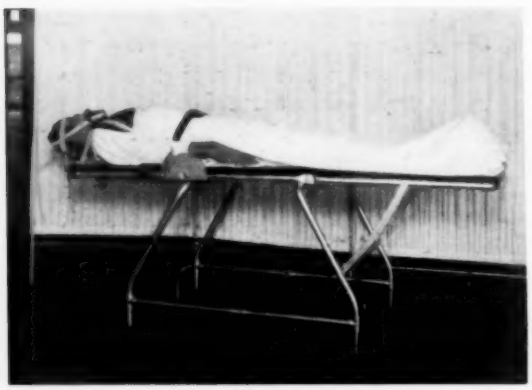

Fig. 1.

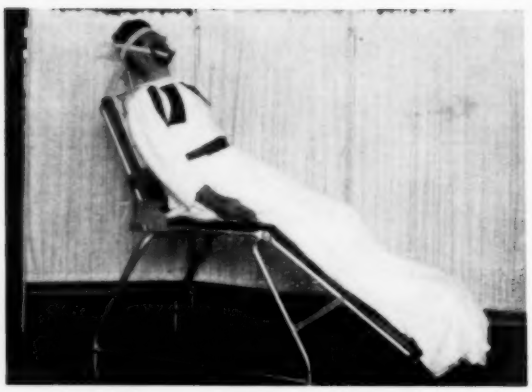

Fig. 2.

For the construction of a suitable apparatus, certain definite requirements had to be met. During the induction of the anesthesia, the patient should be held in a recumbent position. Since the patient is in a state of muscular relaxation, it is necessary to hold the patient securely as the change to the sitting position is made. Fur-

Fig. 3.

* From the Boston Psychopathic Hospital.

[1] Solomon, H. C., and Epstein, S. H.: Encephalography under narcosis produced by nonvolatile anesthetics. *J. Am. M. Ass.*, 1932, *98*, 1794–1796.

thermore, the security of the patient in the upright position must be maintained while the lumbar puncture is being done. For the air injection, it is important to be able to obtain various angles of the sitting position. This makes for the filling of both the subarachnoid spaces of the head and the ventricles. It has been pointed out previously that the best filling of the ventricles is obtained when the head and trunk are in the erect position, whereas with the head and trunk bent forward or backward, the subarachnoid spaces are more readily filled. To ensure complete emptying of the cerebrospinal fluid system and the replacement by air, it is considered advisable to move the head from side to side, and backward and forward at the neck as the air injection proceeds. In order to allow for flexion, extension and rotation of the head, a movable head rest is required, which will hold the head in any desired position with a minimum of adjustment. Finally, it was desired to design an apparatus which could be used

Fig. 4.

Fig. 5.

as well by the roentgenologist in the making of the encephalograms with the least disturbance to the anesthetized patient.

The apparatus described herein, we believe, fulfills these conditions. As may be seen in Figure 1, it consists of a flat stretcher of iron pipe, with wooden inserts, mounted on wheels. It is so arranged that it can be broken at the knees and hips to obtain various angles of the sitting position (Fig. 2). Bending at the hips is controlled by a ratchet and sliding bolt device, so that the patient's trunk can be bent forward and held in any desired angle, as shown in Figure 3. In order to drop the knees, the distal segment of the stretcher is arranged to descend through an arc and its descent is controlled by two notched curved bars which lock on a cross piece.

The patient is held in the chair by a heavy abdominal strap, fastened to both sides of the upper segment of the stretcher, and also by two shoulder straps. The latter pass from the back of the stretcher through

FIG. 6.

the opening in the wooden insert to the front and over the anterior aspect of the shoulders, and then continue over the back of the patient, and are fastened by buckles on the back of the wooden frame. Figure 3 shows how the patient is held in the sitting position by the head piece and abdominal and shoulder straps. The attachments of the shoulder straps are seen clearly in Figure 4. The close-up (Fig. 5) demonstrates the shoulder straps passing under the patient's axilla, which is protected by a felt pad, and then over the shoulders to be fastened behind.

As noted in the photographs, the height of the head piece is controlled by a square rod which slides up and down through a square opening in the upper end of the stretcher. This may be fixed in any desired position by a set screw. Forward and backward motion of the head piece may be accomplished by a revolving device superimposed upon the iron pipe across the upper end of the stretcher. The forward and backward swing of the entire head piece is controlled by another set screw which fixes the square opening in the upper end of the stretcher as it rotates on its transverse axis. The combination of these two set screw adjustments allows up and down, forward and backward, movements of the head piece. In addition, there is a universal joint at the lower end of the head rest, the movements of which are controlled by a screw handle, shown clearly in the close-ups (Figs. 5 and 6). In this way, one can accurately adjust the aluminum cap to the contour of the head and rotate the head in any desired direction, as shown also in Figures 7 and 8.

Figures 4 and 9 demonstrate the manner in which the lumbar puncture and the air injection are done in the upright position. For this purpose, there is a large rectangular opening in the upper segment of the stretcher through which access may be ob-

FIG. 7.

Fig. 8.

Fig. 9.

tained to the usual site of lumbar puncture. We use the two-needle method, allowing the fluid to escape from the lower needle, and injecting the air and registering pressures by means of the upper needle.

We have used the apparatus according to the technique described in our previous paper on encephalography and we have found it extremely useful. The patient lies on the stretcher while the narcosis is induced. He is then brought to the upright position by a ratchet and sliding device described above and held securely by the head piece, abdominal and shoulder straps, while the lumbar puncture is being done. The changes in the position of the head during the injection of air may be easily accomplished by an assistant by means of

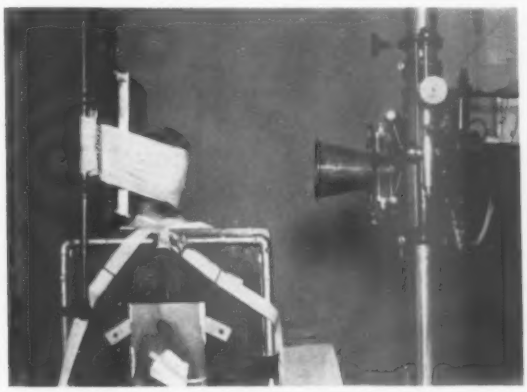

Fig. 10.

Fig. 11.

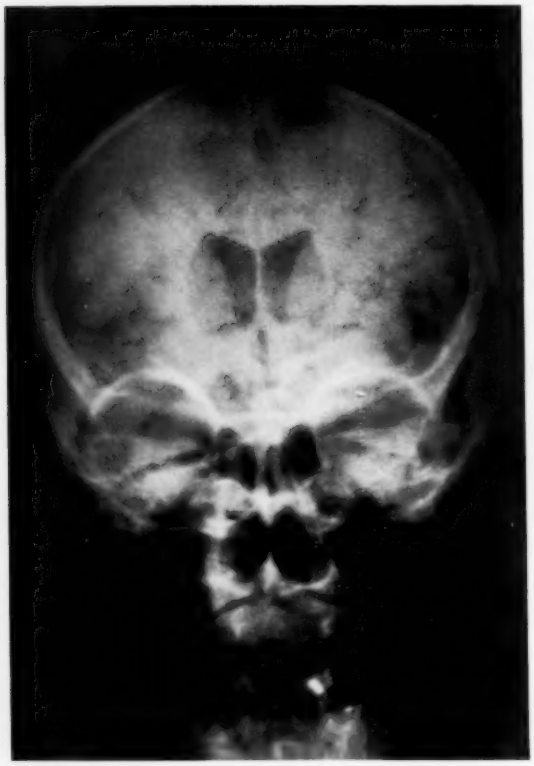

FIG. 12. Normal encephalogram, anteroposterior view.

the screw handles. During this period, the patient is completely anesthetized, and the operator is not disturbed by sponta-

FIG. 13. Normal encephalogram, lateral view.

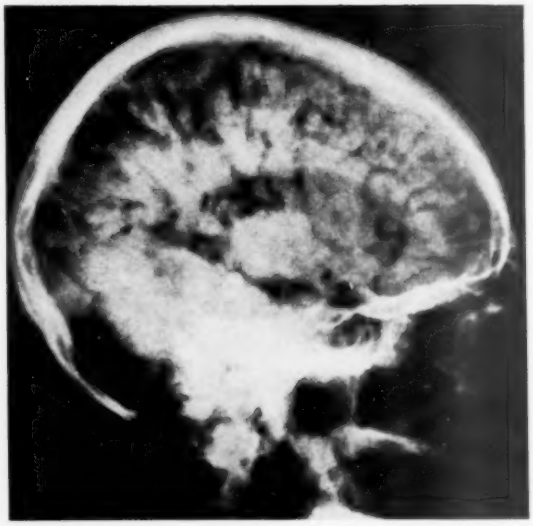

FIG. 14. From a case of general paresis, showing extensive cortical atrophy and enlargement of the ventricles.

neous changes in position of the patient.

The roentgenograms are made with the patient in a state of anesthesia, which enables the roentgenologist to place the head in any desired position and prevents spon-

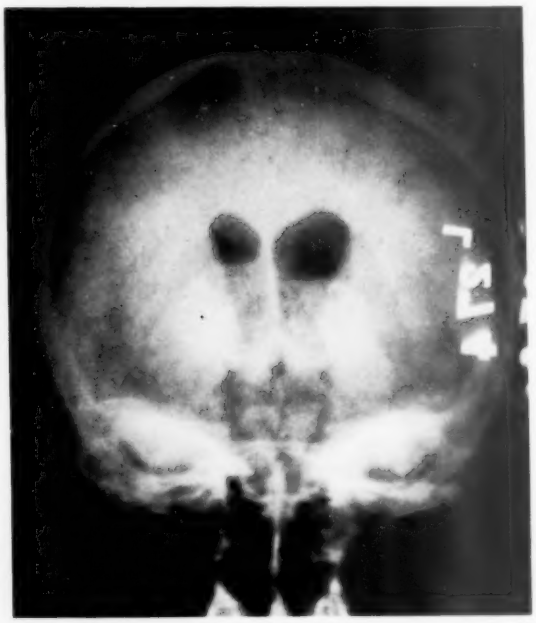

FIG. 15. Unilateral cortical atrophy with enlargement of the lateral ventricle on the same side in a case of chronic encephalitis of long standing.

taneous movement of the head while the roentgen exposure is being made. By the use of the encephalography chair, roentgenograms of the head in the erect position may be made, the patient sitting up. For this purpose the roentgenologist is further aided by a device* shown in Figures 10 and 11. The roentgen film in its cassette is suspended vertically on a wooden block fastened to a set of iron-pipe cross bars which are firmly screwed into the wall. The patient sitting in the chair is wheeled directly alongside this, and the cassette is lowered so that the head comes in close apposition to it. The cassette may also be tilted forward by a long screw adjustment. This makes it possible to obtain close apposition to the head in taking pictures in the anteroposterior view, as indicated in Figure 11. The roentgen tube may then be rotated in any desired angle in order to obtain various views of the ventricles.

Figures 12, 13, 14, 15 and 16 show the roentgenographic results of the technique as described in this paper.

* This piece of apparatus was designed and constructed by Mrs. Anna Morgan, x-ray technician, and Mr. Jesse Philips, chief engineer.

Fig. 16. Enormous enlargement of the lateral ventricle in a case of general paresis.

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ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

ROENTGEN AND RADIUM THERAPY

Gibert, Paul. Évolution d'une lymphogranulomatose. (Evolution of a case of lymphogranulomatosis.) *Bull. et mém. Soc. de radiol. méd. de France*, June, 1931, *19*, 273–278.

The author discusses in lengthy detail a case of lymphogranulomatosis which he observed from its earlier stage and which following the administration of roentgen therapy lived for a period of over five years. The interesting feature is that the application of very large doses of roentgen rays (a total of 31,000 r given over the clavicular region for a period of five years with 0.5 mm. Zn or 10 mm. Al) failed to produce any noticeable changes of the skin such as telangiectasis or atrophy. Thus it seems that by fractionating the dose and by spacing it properly one can administer an unlimited amount of radiation over a certain area.—*T. Leucutia.*

Nemenow, M. Neue Wege bei der Leukamiebehandlung. (New method of treating leucemia.) *Strahlentherapie*, 1931, *41*, 77–85.

The author refers to the work of Jugenburg and Tschotschia, done in his clinic, which shows the importance of purin metabolism in leucemia. The severity of the clinical picture depends on the amount of uric acid in the blood and urine. The better the condition of the kidneys, the better chance the organism has to overcome the disease. He has found by autopsy and histological examination of the kidneys that they are very frequently infiltrated with myeloid or lymphoid tissue, depending on the kind of leucemia the patient has. This exercises pressure on the kidney parenchyma and impairs its function, and of course the flooding of the organism with the toxic products of albumin catabolism also impairs kidney function.

He therefore proposes irradiating the kidneys before giving the usual irradiation of the spleen or bone marrow and lymph glands. He irradiates first the right and then the left kidney, the right first in order to avoid irradiating the spleen at the same time. In favorable cases after irradiation of the kidneys with a dose of 225–250 r there is a rapid decrease of the uric acid in the blood and an increase of that in the urine. This shows that the "blockade" of the kidneys has been overcome. Then the usual irradiation of the spleen or of the bone marrow and lymph glands is given. He also keeps the patients on a diet as free of purin as possible. The roentgen doses must be small to avoid flooding the organism with products of cell disintegration.

Two typical cases are described in which there was great improvement after irradiating the kidneys, though in one of them the patient had grown worse after the usual method of irradiation. It seems probable that a number of the symptoms in subacute leucemia are caused by the accumulation of uric acid and other products of albumin catabolism in the blood and the intoxication caused by them. The ordinary roentgen irradiation in such cases may make the patient's condition worse by increasing the breaking down of cells. The preliminary kidney irradiation frees the blood of the accumulated products of protein catabolism.

The question of whether the rays act on the kidneys only by relieving them of the pressure of the lymphoid or myeloid infiltration or whether in some way they increase the function of the secreting kidney cells is as yet unsettled. It has been shown that roentgen irradiation may increase diuresis.—*Audrey G. Morgan.*

Jugenburg, Anna, and Tschotschia, K. Neue Ergebnisse zum Verständnis des Leukämieverlaufes. (New information in regard to the course of leucemia.) *Strahlentherapie*, 1931, *41*, 86–100.

In leucemia the blood is flooded with enormous numbers of leucocytes which are destroyed rapidly so of course there are profound disturbances of purin metabolism. The authors made a study of purin metabolism in 46 cases of leucemia, 21 of the myeloid form and 25 of lymphatic leucemia. They describe illustrative cases and give curves showing the number of leucocytes, the amount of uric acid in the blood and in the urine and the uric acid quotient, that is, the proportion between the uric acid in the blood and that in the urine. The normal

amount of uric acid in the blood is 3–4 mg. per cent and the normal amount in the urine is 0.5 to 0.6 gm. This gives a normal uric acid quotient of 6–6.6. The quotient may be increased in leucemia as a result of increased destruction of leucocytes and consequent accumulation of uric acid in the blood or as a result of decreased excretion through insufficient kidneys. In the roentgen treatment of leucemia in the favorable cases there is increased excretion of uric acid in the urine and therefore a decrease of the quotient. In cases of leucemia that show an unfavorable course there are serious changes in the kidneys. These changes are partly degenerative in nature and partly brought about by myeloid or lymphoid infiltration of the kidneys. In fatal cases there is always decreased excretion of uric acid and accumulation of it in the blood. In the roentgen treatment of leucemia it is just as important to determine the uric acid quotient as it is to make blood examinations. Any considerable increase in the quotient shows threatened intoxication. In the treatment of leucemia care must be taken to relieve the body of both endogenous and exogenous uric acid. So the diet must be as free of purin as possible and in roentgen treatment as small doses as possible must be used. It must be assumed that every patient with leucemia has more or less insufficient kidney function.—*Audrey G. Morgan.*

Huet, J. A. Nouvelles observations des effets de la radiothérapie de la région hypophysothalamique. (New observations of the effects of radiotherapy of the hypophyso-thalamic region.) *Bull. et mém. Soc. de radiol. méd de France*, Nov., 1931, *19*, 450–451.

In a previous article (see abstract this Journal, July, 1931, *26*, 133–134) the author, on the basis of two clinical observations, expressed the opinion that roentgen therapy of the region of the pituitary gland acts also on the regulatory center of water metabolism, a close association existing between the two. Numerous observations since that time induced the author to somewhat change this opinion. He now believes that the good effect is due to the action of the roentgen rays on the choroid plexus which, as is known, is very radiosensitive. There is also a difference between the response of the anterior and posterior lobes of the hypophysis, this latter being the more radiosensitive of the two. In several instances with congestion of the posterior hypophyseal lobe good results were obtained from irradiation.—*T. Leucutia.*

Wassink, W. F. Die postoperative Röntgenbestrahlung des Brustkrebses in der Klinik des Niederländisch Krebsforschungs-instituts. (Postoperative roentgen irradiation of cancer of the breast at the clinic of the Netherlands Cancer Research Institute.) *Strahlentherapie*, 1931, *42*, 753–758.

The author uses a classification which he thinks more practical than the one usually in use. He divides the cases into four groups: A1 without metastases, A2 with central metastases in the axilla, B1 with peripheral metastases in the axilla and B2 with metastases that have extended beyond the axilla. In the first two groups the cancer is probably localized. Ordinarily the last group is considered inoperable and not counted in surgical statistics. He discusses his results in 137 cases, 38 in group A1, 23 in group A2, 31 in group B1 and 45 in group B2. In the first group 28 are still alive, 8 have died of intercurrent disease and 2 of recurrence or metastasis. In the second group 15 are still alive and 8 have died of recurrence or metastasis; in the third group 4 are still alive, 4 have died of intercurrent disease, 22 of recurrence or metastasis and 1 is unknown; in the fourth group 4 are still alive, 3 have died of intercurrent disease and 38 of recurrence or metastasis. All these cases have been under observation for from three to seven years, making a percentage of recovery for from three to seven years in 93.3 per cent of the first group, 65.2 per cent of the second, 14.8 per cent of the third and 9.5 per cent of the fourth. This is better than the results reported in most statistics. He attributes this to the fact that his method prevents subcutaneous recurrences.

He performed a typical surgical extirpation, cleaning out the axillary and infraclavicular spaces and in a few cases the supraclavicular fossa. This was followed by 3 series of roentgen irradiations. The first series of 600 r was given in the course of ten days two weeks after the operation; the second series of 400 r was applied in five days six to eight weeks after the operation; the third series of 400 r was given in five days ten to fourteen weeks after the operation. The irradiation was given over 4 fields, one supraclavicular, one in the axilla and two large fields tangent to the thorax.—*Audrey G. Morgan.*

LYNHAM, J. E. A. Pre- and post-operative treatment of cancer of the breast by radiation (metastasis excluded). *Brit. J. Radiol.*, Nov., 1931, *4*, 534–560.

This paper represents the present concepts on the value of pre- and post-operative radiation in cancer of the breast, as delivered in the joint session of the Third International Congress of Radiology in Paris. The author emphasizes that whereas he has collected information from many papers in the literature, from private communications and personal observations, he does not hesitate to incorporate ideas which are not widely accepted.

All early carcinomas of the breast should be treated by operation whenever this can be safely performed. Unfortunately 75 to 95 per cent of all cases already show evidence of more or less wide dissemination when they first come under observation. The results obtained depend not so much on the histology of the tumor as on the stage of involvement. The author endorses in this respect the classification of Steinthal and Anchutz, placing all carcinomas in the three well-known groups. There can be no doubt that the cases belonging to Group I owe their lives to surgery, whereas in Group III no appreciable effects are produced. It is in Group II that radiation as a therapeutic measure is put to test in conjunction with surgery whether before or after operation. In surgery alone the figures for three-year survivals in this group are given as 50 per cent, while with postoperative irradiation the number is 75 per cent. The five-year figures are given as 40 per cent for surgery alone and 56 per cent for surgery followed by roentgen irradiation.

The value of the three or five-year survival percentage is open to discussion. From the figures of the London Medical Society the critical period for recurrence appears to be the first three years and there is a further period of danger from eight to ten years after the excision. It would almost seem that there is a periodicity in the reaction of a carcinoma to the forces of resistance in the host.

Concerning the value of pre- and post-operative irradiation no definite conclusions can be reached as yet. It seems that preoperative irradiation whenever applied should aim at the inhibition of the active carcinoma cells and therefore it should be relatively intense. The postoperative irradiation has a double duty to perform: first, it should affect the unsuspected, actively dividing cells growing in the tissues, and therefore the first series of exposures should in general follow the principles of preoperative irradiation. Afterwards the question of latent cells has to be considered and it seems probable that they can be controlled only by divided doses extended over a prolonged period and including wide areas of the body. With this aim in mind, British radiologists, including the author himself, use a technique resembling somewhat that of Pfahler, but not so rigid in detail. An effort is made at the beginning to produce a mild reaction in the tissues, which is followed up by spaced out treatments extending over two or three months, followed by an interval and repeated with diminishing intensity.

It has become the practice of many surgeons to use radium needles in the tissues in the line of lymphatic drainage at the time of operation. Whereas the radium needles may be successful in many cases it seems to the author that the technical limitations do not as yet permit the general use of such a method, or if used it should be followed up by a prolonged course of roentgen rays spaced out as a prophylactic measure.

The author concludes by stating that it is time that the enormous value of radiation treatment in the hands of skilled operators should be recognized. It must be admitted, however, that in the opinion of many the case is not yet proved. Much harm has resulted from the efforts of men whose training and experience is inadequate. In England there is established a central body, the British Institute of Radiology, which has acquired an important position in relation to all aspects of radiologic practice and procedure and particularly with regard to education. It is increasing its influence from year to year.

A voluminous bibliography is appended.—*T. Leucutia.*

MARCHIONI. Radiothérapie profonde dans les laryngites hypertrophiques. (Deep radiotherapy in hypertrophic laryngitis.) *Bull. et mém. Soc. de radiol. méd. de France*, Oct., 1931, *19*, 416–419.

Five cases of hypertrophic laryngitis were treated successfully by roentgen therapy: 0.3 mm. Cu and 2 mm. Al, 200 kv., 28 cm. distance, field 9 cm. in diameter, total surface

dose of 3000 R, two lateral fields centered over the superior region of the larynx, 6 seances of 500 R each, one seance every second day. Anatomically a disappearance of the hypertropic lesions of the larynx, with diminution in the thickness of the vocal cord and functionally a complete relief of the symptoms with disappearance of the hoarseness, laryngeal irritation, pain and dysphagia was obtained. The method is entirely harmless.—*T. Leucutia.*

Serrand, J. Roentgenthérapie de la maladie de Basedow. (Roentgen therapy of Basedow's disease.) *J. de radiol. et d'électrol.*, Aug., 1931, *15*, 447–450.

Good results have been obtained from the roentgen irradiation of Basedow's syndrome at the Roentgen Laboratory of Saint Louis Hospital in Paris for a number of years. One may distinguish three large groups of the syndrome: (1) true Basedow's disease; (2) Basedow syndrome without goiter, and (3) toxic goiter.

The technique of irradiation was as follows: Standard Coolidge tube, 135 kv. maximum, filtered with 1 cm. Al (in case of huge goiters or refractory response 200 kv. max., with 0.5 mm. Zn and 2 mm. Al or even with 1 mm. Cu and 2 mm. Al), two lateral fields extending widely over the manubrium sterni so as to include eventual aberrant thyroid and the thymus (in huge goiters three fields) exposed simultaneously, 3 H or 600 R (Solomon) per field, treatment being repeated not sooner than fifteen days for a total of six to eight seances; after two months' rest a second series, and following another rest of three months, perhaps a third series.

Very good results were obtained in the true Basedow form and in the Basedow syndrome without goiter, whereas in toxic goiter the results remained unfavorable.

The author also discusses the immediate action of the roentgen rays, the chronologic disappearance of the various symptoms as well as the local and general complications which may arise. He finally concludes with the statement that roentgen therapy represents the method of choice for the forms mentioned, surgery being reserved only for the very acute cases and those refractory to irradiation.—*T. Leucutia.*

Chaumet, G. Technique de polyradiothérapie associée a la médication interne dans les décalcifications localisées. (Technique of polyradiotherapy associated with internal medication in localized decalcifications.) *J. de radiol. et d'électrol.*, Sept., 1931, *15*, 510–515.

In cases of fractures with insufficient callus formation, the authors stimulate the local calcium deposit by proceeding thus: (1) Small repeated doses of roentgen rays are administered over the affected area, 150 R with 15 mm. Al filter, 130 kv., 22 to 31 cm. skin target distance, one seance every day or every other day until a total of 1,800 to 2,000 R is reached. The number of fields depends on the dimensions of the anatomic region, as for example, one external and internal field for the ankle, one anterior and two lateral fields for the thigh, etc., the duration of the irradiation being about fourteen days. (2) Application of ultraviolet rays every second day, with large fields over the thoraco-abdominal region, one exposure anterior and one posterior, the duration being 4 to 5 minutes in the beginning and gradually increased to 25 to 30 minutes, whereas the distance diminishes from 1 meter 50 cm. to 0.90 cm. The series comprises about 18 to 20 exposures, depending on the reaction produced. (3) Internal medication of calcium phosphate for a period of fourteen days (calcium glycerophosphate and tricalcium phosphate, $\overline{aa}$ 0.50, two capsules per day).—*T. Leucutia.*

Desplats, R. Études thérapeutiques sur la radiothérapie fonctionnelle neuroglandulaire et particulièrement sur la radiothérapie de la région des capsules surrénales. (Therapeutic studies on functional neuroglandular radiotherapy and particularly on radiotherapy of the region of the suprarenal capsules.) *J. de radiol. et d'électrol.*, Sept., 1931, *15*, 502–509.

The author, in association with Langeron, has carried out a series of researches on functional neuroglandular roentgen therapy during the past four years. It may be said now (1) that functional roentgen therapy has definitely established its value in arterial hypertension, arterial obliterations of the extremities and vasomotor disorders; (2) that some interesting results are obtained in diabetes mellitus, the moderately advanced cases responding rather

favorably whereas, in the advanced cases, no response or even aggravation is obtained, and (3) that recent casual results obtained in painful osteoporosis, physiopathic disorders and chronic rheumatism, justify its further investigation concerning the therapeutic value in these diseases.

The technique used by the author is that indicated by Cottenot, the irradiation being directed to the paravertebral region between the second dorsal and third lumbar segments, 12×12 cm. fields, 130 kv., 5 to 7 mm. Al, the total dose amounting to 2,000 R, generally divided into four seances over the two fields. The roentgen therapy of the suprarenal regions is practised with doses of 500 R per seance for a total of 1,500 to 2,000 R over each suprarenal region.

The results obtained in the various above-named lesions, as well as the therapeutic action and immediate response, are discussed in detail.—*T. Leucutia.*

Piffault and Surmont, J. Radiothérapie sympathique péri-artérielle. (Periarterial sympathetic radiotherapy.) *Bull. et mém. Soc. de radiol. méd. de France*, Oct., 1931, *19*, 367–368.

Good result was obtained in a case of trophic ulcer of an amputation stump of the leg by periarterial sympathetic roentgen therapy with the following technique: 1200 R (Solomon) per field, 0.5 mm. Zn and 1 mm. Al, 30 cm. distance, 42 cm. spark gap, 12×12 cm. fields, in the respective order—anterosuperior femoral, anteroinferior femoral, popliteal space, posterior aspect of stump. The treatment was given every four days, a notable improvement occurring after the third exposure and complete cicatrization after the twelfth. It is notable that other methods of treatment which were tried before the institution of roentgen therapy remained without benefit.—*T. Leucutia.*

O'Brien, F. W. The x-ray treatment of Hodgkin's disease. *Radiology*, Dec., 1931, *17*, 1197–1207.

A short history of the disease is given. In the discussion as to whether Hodgkin's disease is a malignant tumor or an infectious granuloma, Virchow, Kundrat, Oliver, Mallory, Lævin, and Warthin, are cited as favoring the former view.

While one thinks of Hodgkin's disease as associated with lymph glands, liver, and spleen, one must not forget that it manifests itself in other places; i.e. orbit, spine, and long bones. In evaluating the results of treatment one must remember the significance of age and sex in relation to duration of the disease. Individuals under thirty-four years are subject to the acute form, followed by early death. Women live longer than men.

Minot and Isaacs feel that it is exceedingly easy for irradiation to cause rapid dissemination of Hodgkin's disease; but the author believes this has no firm foundation. At the Boston City Hospital radiation using moderate voltage was used from 1919 to 1928 (145 kv., 0.25 mm. Cu and 1 mm. Al). Fractional doses were given only to palpable or objective sites of the disease. Lately high voltage has been used (185–200 kv., 1 mm. Cu and 1 mm. Al). No prophylactic treatment is given to unaffected areas.

Irradiation offers in the majority of cases definite palliation and not only retardation of the growth but an improvement in general health.—*Ellsworth Johnson.*

Michel, Max. Röntgenbehandlung von Berufskrankheiten der Schuhindustrie. (Roentgen treatment of occupational diseases in the shoe industry.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, Dec., 1931, *44*, 766–770.

Since 1928 the author has treated several cases of occupational diseases occurring in the shoe industry. One of the most frequent conditions encountered was "knocker's disease," which is an angioneurosis due to the effect of the continuous vibration of the machine on the hands and which is very similar to Raynaud's disease. As in this, ulcerations and even gangrene of the fingers are not infrequent in the later stages.

Roentgen treatment consisted in the use of copper filtered radiation with small fractional doses given over a period of two to three months, through several fields, 5 to 15 per cent S.U.D. with 160 kv., per field. The irradiation extended along the vertebral column from the level of the sixth and seventh cervical vertebrae down to the level of the third lumbar vertebra, but precaution was taken not to include the adrenals and the spleen in the field of irradiation. Subjective improvement as well as regression of the objective phenomena was observed in all irradiated cases.—*T. Leucutia.*

Zaccaria, A. A. 44 cas d'adénome de la prostate traités par la roentgenthérapie; description de ma technique personnelle. (Forty-four cases of adenoma of the prostate treated by means of roentgen therapy.) *J. de radiol. et d'électrol.*, Dec., 1931, *15*, 693–696.

After discussing the pathology, clinical symptomatology and operative results in simple hypertrophy of the prostate, the author expresses the opinion that roentgen therapy should constitute the method of choice, inasmuch as it is a very simple procedure and leads, in contradistinction to surgery, to practically no recurrence.

The technique of the author is as follows: The gloved index finger, which on its end has a small lead cap for landmarking, is introduced into the rectum until it reaches the prostate and then the roentgenoscopic projection of the lead for the various positions marked on the surface of the skin. Thus the prostate is exactly localized and the central ray is directed toward it. Four portals are used—two suprapubic (one over each side), one anoperineal and one sacral, 220 kv., 0.5 mm. Zn plus 4 mm. Al as filters, 2 ma., 10×15 cm. fields, 30 cm. distance, a full erythema dose being administered over each portal, the series being repeated within five to six weeks.

The results obtained were quite remarkable, a symptomatic improvement being observed within fifteen to twenty days following the first treatment and a reduction in the size of the prostate to that of normal within about three months.—*T. Leucutia.*

Mayer, A. Zur Vorbestrahlung des Uteruskarzinoms. (Preoperative irradiation of carcinoma of the uterus.) *Strahlentherapie*, 1932, *42*, 759–768.

A great deal of the former high operative mortality in cancer of the uterus was due to peritonitis from suppuration of the tumor. Preoperative irradiation overcomes this suppuration and makes the field of operation aseptic. This was what led the author to begin preoperative irradiation. At first he used only roentgen rays by the Dessauer-Warnekros method, later roentgen rays and radium combined and more recently radium alone almost exclusively. At first he only irradiated suppurating tumors but later all cases, whether suppurating or not, as there may be latent infection.

The primary results have been very satisfactory. The operative mortality has been greatly reduced. In the few cases that died the suppuration was not controlled by the irradiation. There will probably always be a few such cases. In many cases the parametritis that accompanies the carcinoma is inflammatory and not carcinomatous in nature and apparently inoperable cases can be rendered operable by preliminary irradiation.

The author does not believe, however, that operation can be replaced by irradiation alone for in many cases in which there is clinical cure removal of the uterus shows that it still contains carcinoma cells. The late results of irradiation followed by operation compare favorably with those of operation alone and irradiation alone.

The argument against preliminary irradiation that it hardens the tissues and makes later operation more difficult and increases the danger of injury of the ureters and bladder he had found not to be true.—*Audrey G. Morgan.*

v. Büben, Iwan. Die Strahlenbehandlung des Korpuskarzinoms. (Radiotherapy of carcinoma of the body of the uterus.) *Strahlentherapie*, 1932, *42*, 769–774.

The prognosis in carcinoma of the body of the uterus is better than that of any other genital carcinoma because it remains localized so long. Operability is high therefore and irradiation is indicated only in inoperable cases. Some cases that are operable anatomically, however, are inoperable from other causes, such as old age and bad condition of the patient.

The author has used irradiation in 101 cases of carcinoma of the body of the uterus, 45 of them inoperable. He uses radium locally and roentgen rays for the parametrium and glands. As a rule he uses 50–75 mg. radium in silver-brass tubes, corresponding to a filter of 1 mm. platinum. The dosage of 2,400–3,600 mg-hr. is generally given all at once. To supplement the intrauterine treatment 2,000–2,400 mg-hr. is given in the vagina. For external treatment he gives three roentgen irradiations over 2 to 6 fields. Each field is given 3/4 of a skin erythema dose or 470 r measured in air, radiotransverter apparatus, Coolidge tube, 183 kv., 5 ma., 0.5 mm. zinc and 0.5 mm. aluminum filter, 30 cm. focus-skin distance.

Of the inoperable cases treated 26 were

treated more than five years ago. The duration of cure in these cases was in 9 cases less than a year, in 5 one year, in 7 two years, in 1 three years and in 1 each five, six, seven and eight years. These 4 cases can be considered cured, which is 15.3 per cent. Among the 19 inoperable cases that were treated less than five years ago 1 has had no recurrence after four years, 2 for three years, 1 for two years and 1 for less than two years.—*Audrey G. Morgan.*

GUNSETT, A. Neuf années de dose fractionnée et étalée dans la roentgenthérapie des cancers, avec quelques remarques sur le dosage intravaginal dans la roentgenthérapie des cancers du col de l'utérus. (Nine years of fractionated and protracted dose in the roentgen therapy of cancer, with some remarks on intravaginal dosage in roentgen therapy of cancer of the cervix uteri.) *J. de radiol. et d'électrol.*, Dec., 1931, *15*, 685–692.

The author since 1922 has abandoned the administration of a single massive dose in the radiation treatment of cancer for daily fractionated irradiation covering a period of fifteen to thirty days. It was found that if the protraction lasts for thirty days, the dose which may be administered augments in the proportion of from 1:2.5 to 3.

In the present article the method of treatment in (1) cancer of the cervix and (2) cancer of the larynx is discussed. In the first, uterovaginal curie therapy was used with preference, except in the advanced cases of stage 3 with invasion of the parametria, in which roentgen therapy alone or roentgen therapy associated with radium was employed. A tabulation of the cases of this last group shows that of 18 cases treated five years ago or longer, 4 (22.2 per cent) have become well and of 44 cases treated three years ago, 10 (22.7 per cent) have become well. The author chooses from four to six portals of entry of 250 to 300 sq. cm., a daily dose of 300 r being administered over one portal, at 40 cm. distance, with 3 ma., for 50 minutes. Since 1928 the dose has been measured by the intravaginal route with the Solomon or Hammer ionization chamber which is left within the vagina during the time of exposure. The total dose is calculated to reach 2000 to 2500 r intravaginally during a period of three or four weeks. To obtain this about 1500 to 1800 r is administered over the surface of each of the four to six portals. The quality of the roentgen rays is 200 kv., with 2 mm. Cu and 2 mm. Al as filters. In case of association with curie therapy, rather large doses of radium are placed within the uterus and in the vaginal vault (40 millicuries-destroyed). (2) In cancer of the larynx, the results have not been as satisfactory and therefore more recently the author changed the procedure by increasing the distance to 70 cm. The technique is as follows: 200 kv., 2 mm. Cu plus 2 mm. Al, 70 cm. distance, daily irradiation with 148 r in 60 minutes, two lateral fields of from 200 to 250 sq. cm., a total dose of 2500 to 3000 r administered in six weeks over each field.

Several dosage charts are included to illustrate the more typical cases.—*T. Leucutia.*

GUILHEM and GOUZY. Les pyométries après traitement du cancer du col de l'utérus par le radium. (Pyometra after treatment of cancer of the cervix of the uterus with radium.) *Presse méd.*, Feb. 13, 1932, *40*, 242–245.

The question of pyometra secondary to intrauterine application of radium is still debated. The authors found that the condition occurred in 8 cases out of a total of 751 cases of uterine carcinoma treated at the anticancer center of Bordeaux, that is, in 1.6 per cent. In studying these cases it was further found that pyometra is the result of a partial or total sclerosis of the uterine cervix brought about by the effect of the radium. The drainage of the secretion of the uterine body through the cervical canal is impaired, thus leading to secondary infection. The modifications produced in the mucous membrane and especially in the glands of the uterus, by the radium a secondary infection at the time of its insertion, a destructive action on the tissues, etc., may act as contributory causes. Clinically the condition may appear within twenty-five days following the radium insertion in the early, and within several months in the later cases. One may distinguish the so-called open type, when there is only partial stenosis of the cervical canal and the closed type, when there is complete stenosis. The latter of course is the more serious of the two, a fatal termination being not infrequent. From the point of view of treatment, it is advised that a correct technique be applied at the time of the radium treatment, that the patients be periodically reëxamined for an early diagnosis and that in case pyometra has already set in, a proper

drainage by the natural route be established in the open cases, and a total or subtotal hysterectomy be performed in the closed cases.—*T. Leucutia.*

Degrais, P., and Bellot, A. La verrue plantaire. Advantages de son traitement par le radium. (Plantar wart; advantages of its treatment by radium.) *Presse méd.*, Dec. 12, 1931, *39*, 1840.

This is a brief practical article dealing with the clinical aspect and treatment of plantar warts. The advantages of radium application as compared to surgery are stressed. Not one single failure was observed in a total of 87 cases treated. The radium is placed usually in the evening and left in situ during the night. The detailed technique is not described.—*T. Leucutia.*

MISCELLANEOUS

Holzknecht, Guido. Die ernsteren Röntgenschädigungen der Röntgenologen und ihre Therapie. (The more serious roentgen injuries of roentgenologists and their treatment.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, July, 1931, *44*, 78–81.

The following more or less serious roentgen injuries are observed in roentgenologists: (*a*) cataract in the periphery of the lens, this having no particular significance; (*b*) azoospermia, which is also insignificant except for nonfertilization, no endocrine disturbances having been noted; (*c*) ovarian changes, the occurrence of which in roentgenologists is not satisfactorily proven as yet; (*d*) keratosis, which may be treated either symptomatically or, in case of infection, with wet dressings or finally surgically (1) with oval excision and suture, (2) with excision and Thiersch graft, and (3) with electrocoagulation; (*e*) non-neoplastic ulcerations which are treated with cleansing (water and soap or eventually glycerine, however, without the use of fats) and occasionally application of one single dose of 100 to 150 R through 1 mm. Al filter; (*f*) malignant growths of the skin; (1) sarcoma, which according to the author never occurs and (2) carcinoma cutis, which as a rule shows a very slow chronic course. The best method of treatment is radical surgical excision followed with extirpation of the regional lymph nodes. It must be mentioned, however, that such carcinomas have a tendency to recur within the adjacent skin necessitating successive mutilating operations or even amputations. It is the author's opinion that roentgen carcinomas do not respond or respond only slightly to irradiation with roentgen or radium rays. Therefore this method of treatment should be used only as an adjunct to surgery in well-selected cases.—*T. Leucutia.*

Dyes, Otto. Das Kombinations-Aufnahmegerät der Firma Hofmann-Brauer. (A combination exposure apparatus of the firm of Hofmann-Brauer.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, May, 1931, *43*, 626–642.

This article is a lengthy description of a roentgen table which can be used in all positions and under most unusual circumstances. The feature is a Bucky diaphragm which can be moved to all parts of the table (so that one may center also over the peripheral parts), and rotated (so that roentgenograms can be made also in oblique positions). The article contains 17 figures illustrating the principle as well as the various positions of the apparatus.—*T. Leucutia.*

Martius, Heinrich. Keimschädigung durch Röntgenstrahlen. (Injury of germ cells by roentgen rays.) *Strahlentherapie*, 1931, *41*, 47–66.

In his discussion of possible injury to the offspring by irradiation of the parents' germ cells, the author makes a distinction between injury of the fetus after impregnation and injury of the germ cell before impregnation, his study being confined for the most part to the ovum, though he points out the importance of roentgenologists protecting the sex glands from repeated irradiation. A number of cases of definite injury of the fetus by irradiation of the mother during pregnancy have been reported. Many children born after irradiation are normal, however, but there is nothing to prove that they have not suffered injuries which may appear in the next or later generations. The possibility of injury of the hereditary constitution must be taken into consideration, and for the purpose of working out the problem the histories of all children born of irradiated mothers or fathers should be kept in some central institute of archaeology or genetics. Experiments have been made on *Drosophila melanogaster*, a species of fly, showing mutations brought about by the use of roentgen rays, but results in plants and

animals cannot be applied to man. The mutation dose in *Drosophila* is very high, but nothing is known of the size of the mutation dose in man, either for mature or young germ cells. Some investigators think that only mature cells are injured, but the author thinks it has not been proved that immature cells are exempt from injury.

As long as the possibilities of injury to future generations are not known it is better to err on the side of safety and give up temporary roentgen castration entirely. It has not proved very reliable or of much clinical value at any rate. And even in diagnostic examinations the dosage should be kept considerably below the minimum that is known to affect the ovary.—*Audrey G. Morgan.*

Antonioli, G. M. Untersuchungen über die bakterientötende Wirkung der Gewebe von gesunden und von röntgenbestrahlten Tieren. (Bactericidal action of the tissues of irradiated and non-irradiated animals.) *Strahlentherapie*, 1931, *41*, 496–509.

There has been considerable discussion as to whether the normal blood and tissues of animals have a bactericidal action. The author reviews the work previously done on the subject and describes his own work, the object of which was to study the bactericidal action of normal blood and tissues, and of the blood and tissues of animals after roentgen irradiation. He used guinea pigs as experimental animals and staphylococci as bacteria. The details of his technique are described.

He found that weak and not too frequent irradiation of guinea pigs increases the bactericidal action of their tissues and organs. The irradiated liver and spleen had the greatest bactericidal action. The number of colonies in cultures of non-irradiated liver and spleen was many times as large as in cultures of these organs that had been irradiated. There was much less difference in the number of colonies in irradiated and non-irradiated kidney and omentum. Lung tissue and striated muscle showed almost no difference in the number of colonies. The skin of the back which served as a portal of entry for the rays showed a marked decrease of bactericidal action.

Intense roentgen irradiation of guinea pigs with large and frequently repeated doses caused a great decrease in the bactericidal action of their tissues. The liver, spleen and kidneys of these animals showed the greatest decrease in bactericidal action, the omentum a less marked decrease. The lungs and striated muscle did not show any change.

It is hard to explain the cause of these facts. Probably the rays cause a true stimulation of cell activity but if the stimulation is too intense it brings about paralysis. It is probable that these biological changes are due to the action of the rays on the reticulo-endothelial cells. This is the only theory that explains the differences in the effect of the rays on the bactericidal action of the different organs and tissues. The difference is due to the varying amount of reticulo-endothelial tissue in the different organs. The author's experiments show that small doses of roentgen rays have a good effect on the protective function of the reticulo-endothelial system, while large doses have a bad effect.—*Audrey G. Morgan.*

Ledoux-Lebard, Petetin and Garcia-Calderon. Sur l'emploi en radiodiagnostic des substances opaques de la série du thorium. (The use in roentgen diagnosis of opaque substances of the thorium series.) *Bull. et mém. Soc. de radiol. méd. de France*, March, 1931, *19*, 95–97.

The inconvenience of certain colloids consists chiefly in the fact that they coagulate or flocculate when rapidly sterilized and that they partially coagulate when coming in contact with organic liquids. The authors are experimenting at the present time with a new colloid solution (25 gm. of thorium dioxide in 100 c.c. of a complex aqueous medium), the so-called Collothor B, which possesses the same fluidity as water and is more stable when sterilized. Furthermore, because of its lesser viscosity it can be injected into narrow canals as, for example, biliary fistulae, with greater ease. The preparation has given very satisfactory results in pyelography, cystography, ureterography and fistulography.—*T. Leucutia.*

Janker, R. Zur Röntgenkinematographie. (Roentgen cinematography.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, Nov., 1931, *44*, 658–668.

After a discussion of direct roentgen cinematography and a perusal of the literature on this subject the author describes his own apparatus which is of great value especially for animal experimentation. The regular cinema

film is used except that the apparatus transports the double length (36 mm. instead of 18 mm.) at each exposure. This necessitated an enlargement of the size of the aperture to 24×36 mm. The entire anterior wall, except the aperture, is protected by lead. On the posterior aspect there is a roentgenoscopic screen (protected by 20 mm. lead glass) which is provided with an observation tube for the eye of the examiner. The four roentgen tubes used for the exposure are rotated synchronously with the transportation of the film. Sixteen exposures are taken per second but through an ingenious device, every image being printed twice (or even four times), a total of 32 (or 64) images per second is obtained. The projection of the film is clear and without jagging or flickering.

The procedure was used chiefly in experimental animals for the study of various motor phenomena (of the heart, pneumothorax, distribution of emboli, arteriovenous fistulae, peristalsis, etc.). In the human the rather large amount of radiation (0.3 to 0.35 R per every single exposure) which is required to take a longer film forms a serious obstacle. Still, 160 images (16 images per second), representing about half of the tolerance dose, may in certain instances suffice for a satisfactory examination. —*T. Leucutia.*

Cottenot, Paul. Présentation d'un appareil sélecteur permettant la stéréoradiographie du thorax et la prise de radiographies du coeur à un temps quelconque de la révolution cardiaque. (Presentation of a selector apparatus permitting stereoroentgenography of the thorax and the taking of roentgenograms of the heart at a certain point of the cardiac revolution.) *Bull. et mém. Soc. de radiol. méd. de France*, June, 1931, *19*, 281–283.

The author constructed an apparatus which permits the automatic taking of roentgenograms of the lungs or of the heart at any point of the respiratory or cardiac cycle. A pneumatic pouch with a belt (fastened around the chest) is used for the respiratory and a sphygmomanometer for the cardiac examination, both being connected to an oscillometer, provided with a small mirror on its axis. The mirror reflects the light of a lamp on a selenium cell connected through an amplifying system to a milliammeter relay which automatically controls the current of the roentgen machine. When the respiratory or cardiac movements reach a set point of the cycle they deflect the mirror on the selenium cell which in turn automatically releases the machine for an instantaneous exposure. The relay is provided with several successive contacts, a variable potentiometer permitting the adjustment to any point of the oscillometric curve.

The apparatus is of great practical importance inasmuch as it permits the taking of roentgenograms at any desired point of the excursion of the respiratory and cardiac cycle. In case of stereoscopic examination of the chest the two roentgenograms can be taken at precisely the same point of respiratory excursion. —*T. Leucutia.*

Boldingh, W. Hondius. Un appareil spécial pour l'examen radiographoque du thorax. (A special apparatus for roentgen examination of the thorax.) *Acta radiol.*, 1931, *12*, 479–485.

An apparatus is described that is designed especially for obtaining great distinctness in pictures of the thorax. It makes use of a tube with a rotating anticathode which can bear an instantaneous charge eight times as large as that of a tube with an equivalent focus and a fixed anticathode. With its use a great deal of contrast can be obtained even with very soft rays in a few tenths of a second with a focus 1.5 mm. in diameter. This greatly increases the distinctness of the picture of the soft tissue of the lung which is in constant motion on account of the pulsations of the heart, so that tuberculous lesions can be detected more readily.

Heretofore it has been possible to take such roentgenograms only with a very powerful apparatus, but in this apparatus the electrical energy is stored in a condenser and discharged into the metalix tube through a large choke-coil. The latter keeps the tension practically constant while the picture is being taken and therefore the apparatus can be used with any ordinary source of current. The apparatus is illustrated. It is a complete cabinet for examination of the thorax with adequate protection from the rays and very easy to manage. It requires about $2\frac{1}{2}$ by $6\frac{1}{2}$ feet of space.—*Audrey G. Morgan.*

Jaubert de Beaujeu, A. Téléradiographie cardio-pulmonaire instantanée à 5 mètres de distance. (Instantaneous cardio-pulmonary

teleroentgenography at 5 meter distance.) *Bull. et mém. Soc. de radiol. méd. de France*, July, 1931, *19*, 341–342.

The author until recently used a distance of 3.50 meters for teleroentgenography of the chest. He has now increased this distance to 5 meters. The procedure has a certain value in teleroentgenography of the cardiovascular system but for the examination of the lungs a distance of 2 to 2.50 meters is more advantageous. —*T. Leucutia.*

CLEMENTE, GIUSEPPE. Ricerche sperimentali sulla irradiazione Roentgen della regione dorso-lombare—regione renale. (Experimental study of roentgen irradiation of the dorsolumbar region—kidney region.) *Radiol. med.*, Dec., 1931, *18*, 1570–1594.

The author irradiated the dorsolumbar region in white rats to determine whether any changes in the kidneys are brought about by such irradiation. The histological findings are described and illustrated with photomicrographs. They showed that doses less than an erythema dose did not bring about any appreciable changes but that larger doses than that caused intense hyperemia followed by primary changes in the convoluted tubules, such as albuminous, granular or even parenchymatous degeneration, vacuolar or hydropic degeneration and necrosis, and secondary changes in the glomeruli. As the process progresses the primary albuminous or necrotic degeneration may be followed secondarily by a catarrhal glomerulonephritis, which is to a certain degree productive. No signs of interstitial nephritis were seen in any of the cases.

Very large doses—3 to 4 erythema doses—caused death of the animals. Smaller doses caused radiodermatitis and epilation, but the kidney changes took place for the most part in cases in which there was no radiodermatitis or alopecia, showing that they were not dependent on the local injury.—*Audrey G. Morgan.*

SAUPE, E. Röntgendiagramme von menschlichen Körpergeweben und Konkrementen. (Roentgen diagrams of human body tissues and concrements.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, Aug., 1931, *44*, 204–211.

The author for the past two years has carried out a series of investigations on roentgen diffraction of various tissues and concrements of the human body. He used a copper anticathode tube which at 40 kv. and 13 ma. yielded only the K radiation of the copper (1.54 and 1.39 Å). The intercalation of a nickel filter would have led to further homogenization by eliminating the 1.39 Å beam but this would have resulted in a very marked increase in the time of exposure. The Koch and Sterzel and the Debye-Scherrer chambers were employed for the exposure. The anatomic material was prepared by either making a very thin section and coating it with collodion so as not to produce too much drying or by pulverizing it and then inclosing it in a collodion capsule. The exposure time amounted to from eight to ten hours in the beginning and to fifty minutes now.

The various substances have given more or less typical roentgen diffraction diagrams which after further perfection of the method may eventually be used for clinical diagnosis. The greatest disadvantage is the comparatively long time of exposure. The recent investigations of Boehm by using the Seemann high tension electron tube aim to eliminate this disadvantage.—*T. Leucutia.*

ALBERTI, W., and DEMETROVIC, B. Über den Einfluss der Totalreflexion auf die Bildgebung bei medizinischen Röntgenaufnahmen. (On the influence of total reflection on the images of medical roentgenograms.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, Nov., 1931, *44*, 649–653.

Köhler in 1916 called attention to the fact that the roentgen image of convex surfaces of bones (arm, thigh, etc.) was associated with the appearance of "overlit marginal stripes" at the outer contours. The authors, after a study of the nature of this phenomenon, express the opinion that the stripes are the result of a reflection of the roentgen rays from the convex (or concave) surface. For this reason, they suggest that the term "sheen-stripes" be used.—*T. Leucutia.*

LEHMANN, H. Auszug aus der Dissertation über "die für die Aufnahme vorgegebener Objekte günstigsten Röhrenspannungen." (Extract from the thesis on "The most favorable tube tensions for the roentgenography of given objects.") *Fortschr. a. d. Geb. d. Röntgenstrahlen*, Sept., 1931, *44*, 375–391.

This is a very technical article dealing with the dependence of the contrast on the tube voltage (kv.) and thickness of the object (filter)

to be roentgenographed. The dependence can be calculated to some extent if constant current machines are used. In other forms of tension curves the matter becomes exceedingly complicated.—*T. Leucutia.*

Coliez, Robert. Die Dosimetrie in der Radiumbehandlung. (Dosimetry in radium treatment.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, July, 1931, *44*, 87–99.

The author is greatly suprised that many roentgenologists still express the radium dose in milligram-hours and millicuries-destroyed, despite the inaccuracy of such a procedure, especially in plastic models and in telecuriether-apy. As is known, the author, in association with Mallet, has constructed an ionomicrometer which permits the measurement of radium doses by an arbitrary unit. This unit, which is called D, corresponds to the amount of gamma radiation which reaches point zero during ten hours' irradiation when the central point of the ionization chamber is at 26 mm. from the axis of a radium tube of 2 mm. platinum thickness containing 10 mg. radium element. The dosage is then expressed in so many D units per day (daily output). This unit represents for radium the same thing as the Solomon unit represents for roentgen therapy. Both are arbitrary but of considerable practical value. It is the author's contention that the present methods of measurement do not permit as yet the expression of the gamma radiation in the International r.

The ionomicrometer and the procedure of measurement are described in detail, a chart for the calculation of the daily output being included.—*T. Leucutia.*

Strauss, S., and Meyer, H. Th. Das Durometer, ein neuer Röntgenhartemesser. (The durometer, a new roentgen hardness measurer.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, Sept., 1931, *44*, 392–396.

The various apparatus employed for the measurement of the hardness of the roentgen rays (Christen, Wehnelt, Benoist, Walter, Schreus) have nearly all been discarded because of their inaccuracy. Recently some changes were made in the Christen instrument making it useful within certain limits. The authors now, by applying the same principle but with further modifications, have constructed a new durometer which permits the measurement of the hardness of all types of roentgen rays (within an error of ± 5 per cent) with considerable ease. The principle is that the roentgen-ray beam affects a fluorescent screen, half of the beam passing unfiltered and the other half through a filter (cellophane in borderline rays, aluminum in superficial roentgen rays, copper in deep roentgen rays and silver in the very hard radium rays) for the determination of the half-value layer. In viewing the fluorescence of the two half-beams, an optic wedge, which is placed in front of the unfiltered half, is rotated until an identical light (fluorescence) is obtained. The procedure is very similar to the half field polarization methods used in the dosage of sugar. If the optic wedge is standardized by means of comparison with an ionization chamber in half-value layers, the precise hardness of the rays can be directly read. It is claimed that the apparatus, because of its great practical importance, will soon replace the other rather cumbersome methods of measurement.—*T. Leucutia.*

Niemann, C. Der zeitliche Verlauf der Röntgen- und Ventilröhrenspannung an Röntgenapparaten in Graetzscher Schaltung. (The timely distribution of the roentgen and ventil tube tension in roentgen apparatus with Graetz connection.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, July, 1931, *44*, 100–108.

The author measured the variation in voltage at the end of the roentgen and valve tubes in the four and six valve apparatus and found that if the apparatus is run without load or with only a small load an increase in the voltage at the roentgen and valve tube terminals results which in the six valve apparatus may reach a percentage as high as 15. This of course represents a considerable danger for both the roentgen and valve tubes.—*T. Leucutia.*

Glocker, R. Prinzipien des Strahlungs- und Hochspannungsschützes und ihre technische Durchführung. (Principles of radiation and high tension protection and their technical application.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, Aug., 1931, *44*, 241–253.

Following a discussion of the fundamental principles of protection against radiation and high tension, the author describes the more recent improvements in the construction of apparatus. Chief among these are the new Metalix and Multix tubes. The principle of the Metalix, as is known, is a chrom iron metallic discharge

chamber which is soldered into the cylindrical glass, thus permitting the surrounding of the tube with protective lead. In the Multix tube the lead is on the outside of the midportion of the cylindrical glass, a bent chrom iron sheet being placed inside the tube. The lead and the chrom iron sheet are electrically connected.

In roentgenoscopic rooms various enclosures, and more recently the Ratkoczi cabin, are used, this latter giving full protection against both radiation and high tension. In deep therapy units lead walls are to be preferred. For a 400 kv. therapy unit recently installed at the Charity Hospital in Berlin, the walls were made of 15 mm. lead.

The danger from high tension is eliminated by specially constructed protective cables (up to 100 kv.) as, for example, in the Metalix apparatus. It is hoped that within a short time the high tension conductors will entirely disappear from the roentgen rooms.—*T. Leucutia.*

Johannés, G. Le tube Roburix. (The Roburix tube.) *Bull. et mém. Soc. de radiol. méd. de France*, July, 1931, *19*, 337–339.

Coolidge, in 1923, for the first time presented a tube with a metallic discharge chamber. The author has pursued another direction and instead of soldering the cylindrical metal chamber into the glass of the tube he has designed a tube which is entirely of glass, two metallic cylinders being placed at the midportion, one within the interior of the glass but separated from this, and the other on the external aspect. This latter consists of lead which serves the purpose of protection. The two metallic cylinders are electrically connected through the glass of the tube. The entire tube is then enclosed in a cylindrical lead shield which is removable. By avoiding the soldering of the metal into the glass electrical accidents are prevented and thus the tube life considerably prolonged. On the other hand, by placing the tube within a lead shield an additional protection is obtained. It was found, for example, that with 100 kv., 3 ma., and 8 hours daily running, it would take, at a distance of one meter, fifty years to produce an erythema.

The central part of the tube which serves for fixation can be connected to ground, this giving adequate electrical and high tension protection. The tube is manufactured with both radiator and water cooling device, all models used for current work being supplied. Because of its extremely powerful construction it is called "Roburix."—*T. Leucutia.*

Lepennetier, F. Le nouveau service d'électroradiologie de l'Hôpital Saint-Louis (Paris). (The new service of electro-radiology of the Saint Louis Hospital, Paris.) *J. de radiol. et d'électrol.*, July 1931, *15*, 377–394. See also Desfosses, P., *Presse méd.*, Dec. 16, 1931, *39*, 1861–1863.

A new department of radiology of which Dr. J. Belot is the director was recently installed at the Saint Louis Hospital, Paris. In these articles, the department, which occupies three floors and is divided into a therapeutic and diagnostic section, is briefly described, numerous photographs being used for illustration. It no doubt comprises the most up-to-date installations.—*T. Leucutia.*

Juul, Jens. The radium station of Copenhagen. *Acta radiol.*, 1931, *12*, 486–496.

A new and enlarged radium station has been erected in Copenhagen in connection with the Finsen Institute. Photographs and plans of the building are given and the history of its development sketched. It is to be used particularly for the treatment of malignant tumors but other conditions requiring radium treatment will be treated also, and this will remove from the patients' minds the fear attached to a cancer hospital. The patients are to be followed up after their discharge and an effort made to obtain complete histories of the results.—*Audrey G. Morgan.*

Hemingway, Allan, and Hansen, C. O. Temperature distribution in local diathermy treatments. *Radiology*, Dec., 1931, *17*, 1258–1261.

The actual rise of temperature at the surface and in the subcutaneous and intramuscular layers was observed during diathermy treatment. There are two charts giving findings with a pad electrode and metallic electrode. Currents of 11.6 and 10.0 ma. per sq. cm. were used.

The conclusions derived are that surface heating is much less with the pad electrodes; for a short treatment lasting about twenty minutes, a greater temperature can be obtained with a metallic electrode; for a treatment lasting an hour or longer by using pad electrodes, the same heating effect is obtained with less

superficial heating in a long treatment. In cases where a higher deep temperature is desired with a low superficial temperature, the pad electrode is to be recommended with a treatment of one hour or longer. For rapid superficial heating, the metallic electrode is used.—*Ellsworth Johnson.*

Wyckoff, Ralph W. G., and Luyet, B. J. The effects of x-rays, cathode, and ultraviolet rays on yeast. *Radiology*, Dec., 1931, *17*, 1171–1175.

Preliminary results are recorded of the effects of roentgen-rays, cathode rays, and monochromatic ultraviolet light upon yeast (*Saccharomyces cerivisiae*). Control irradiations of culture medium with doses far in excess of those needed in these experiments showed that the destructive action of the radiation is directly upon the cells themselves and not upon their food material. The progressive stages of injury make it difficult to set up a precise criterion of lethal action. It is observed that yeasts, unlike bacteria, can be injured without being killed outright. Injury with either cathode rays or roentgen rays is followed by the development of an extraordinarily large number of two-celled colonies, which on prolonged incubation ultimately die without further budding. Yeast looses its ability to multiply long before it is killed. The destructive action of formaldehyde resembles that of ultraviolet light. These experiments give no indication that small doses of radiation have any stimulative effect upon the growth of yeast. The article is supplemented with two tables and two figures.—*Ellsworth Johnson.*

Zanelli, Arturo. Un nuovo modello di orientatore e fissatore per radiografie del cranio. (A new apparatus for orientation and fixation in roentgenograms of the skull.) *Radiol. med.*, May, 1931, *18*, 647–651.

The author describes an apparatus which he himself devised for fixation of the head in taking roentgenograms and marking the exact position in which the picture is taken so that if the examination needs to be repeated the head can be fixed in exactly the same position and exactly the same projection obtained. It consists essentially of a special cap for the head and graduated angular and linear scales fixed to a specially constructed frame. Movable indicators show the exact position on the scales. An antidiffusion diaphragm can also be used with the apparatus. The apparatus and its different parts are illustrated.—*Audrey G. Morgan.*

Baastrup, Chr. I. The prophylactic and therapeutical value of the lateral position for bed patients. *Acta radiol.*, Feb. 14, 1931, *12*, 23–27.

Not infrequently when it is necessary to put old people to bed they develop hypostatic pneumonia and die. Generally these patients are unable to sit up in bed. But the author finds that a very effective method of preventing hypostasis is to let them lie for half an hour morning, noon and evening, on the right side, and then for half an hour on the left side. The roentgen picture of the lower lung is always slightly darker than that of the upper one, showing that the former is compressed and the latter expanded. The pulsation of the heart also has a massaging action on the lower lung, and the temporary shifting of the blood's weight is also important, as this weight and the constant stagnation of the fluid in one place are the cause of hypostasis. None of the old patients with whom the author has used this method have contracted hypostatic pneumonia. In one old patient signs of hypostatic pneumonia began but disappeared a few days after this method of treatment was begun.—*Audrey G. Morgan.*

Van Allen, C. M., and Lindskog, G. E. Collateral respiration in the lung; rôle in bronchial obstruction to prevent atelectasis and to restore patency. *Surg., Gynec. & Obst.*, July, 1931, *53*, 16–21.

In a series of experiments with the lungs of the dog, cat, rabbit and man the authors have found that the branches of the bronchial tree in a single lobe of the lung intercommunicate at the periphery in such a manner as to permit the transfer from one to another of gases, fluids, and particulate matter. The process of transfer is referable both to diffusion and to passage through minute openings, but this point requires further investigation. The airways of two neighboring lobes do not so communicate.

This bears economic significance to respiratory function after bronchial obstruction; for a lobule of lung with centrally obstructed bronchus may yet breathe satisfactorily by

using the peripheral interconnections with adjacent free lobules. This is termed collateral respiration.

Collateral respiration plays two economic rôles in the lobular form of bronchial obstruction, namely, that of preventing the development of atelectasis, and that of rendering important assistance to the broncho-eliminative forces.

Collateral respiration may be excluded by closure of those airways along the margins of the obstructed lobule which have to do with the intercommunication. This may result from blockage with secretions or other materials or from shut-down during periods of shallow breathing. The latter circumstance is probably a factor in the pathogenesis of postoperative atelectasis.—*R. R. Rathbone.*

Åkerlund, Åke. Ein Lichtstempel für Filmbeschriftungszwecke. (An apparatus for marking films.) *Acta radiol.*, Feb. 14, 1931, *12*, 95–99.

It takes a great deal of time to mark films by hand and the author describes an apparatus for labelling them which photographs a line of text containing the name of the patient and any other desired information, such as the half of the body photographed, the position of the body, direction of projection, number of hours since the last meal, etc. The apparatus is illustrated; it is a simple box with a ground glass window and a white light for photographing the text on the bottom of the film.—*Audrey G. Morgan.*

Thoraeus, R. On the proper use of different roentgen tubes regarding the radiographic quality in diagnostic work. *Acta radiol.*, Feb. 14, 1931, *12*, 85–94.

The author discusses the projecting properties of different roentgen tubes. On the basis of the results obtained with different tubes, he studied the working condition of the tubes in relation to the geometrical conditions of projection, and gives a simple method of calculating the right conditions in each case. In order to show the value of the method he gives a detailed discussion of the roentgen diagnosis of the lungs, skull and spinal column.—*Audrey G. Morgan.*

Vanoni, Enzo Pugno. Le variazioni di tensione delle rete in radiologia. Un apparecchio autoregolatore. (An apparatus for the automatic regulation of the output of roentgen tubes when there are changes in the tension of the electrical system.) *Radiol. med.*, Apr., 1931, *18*, 463–476.

An industrial electrical system is supposed to furnish a supply of electrical energy at constant tension, but it rarely does so. The author discusses the various factors which bring about changes in tension and the effect on the yield of roentgen tubes produced by such changes. He then discusses the various sorts of stabilizers used for diagnostic and therapeutic roentgen apparatus and points out the defects which have kept them from being generally adopted. He then shows how the yield of roentgen apparatus can be regulated automatically by means of a transformer with a movable coil. He gives a diagrammatic sketch of an apparatus so regulated and describes the way in which the transformer functions. He gives figures based on experimental work showing that when this transformer is used even variations of 25 per cent in the tension of the current do not affect the tube, while without it a variation of even 5 per cent affects it seriously. He shows how these stabilizers may be applied to apparatus already installed and that the construction of the stabilizer is so simple that it cannot fail to function properly.—*Audrey G. Morgan.*

Luboshez, B. E. Cineradiografia. (Cinematic roentgenography.) *Radiol. med.*, Apr. 1931, *18*, 450–457.

Ever since roentgen rays were discovered attempts have been made to develop cinematographic roentgenography. In 1911 Lomon and Comandon succeeded in making cinematographic roentgenograms of normal rapidity but unfortunately the milliamperage and voltage required were so enormous that neither the patient nor the roentgen apparatus could stand them.

In 1927 the author succeeded in producing cinematographic roentgen pictures with an ordinary roentgen installation and without injuring the patient. The problem was to obtain 16 photographic images in a second on a strip of film without harm to the patient or the installation. He found that this could not be done directly and adopted the indirect method consisting of taking the cinematographs from a fluorescent screen by means of a special optic

system. In this way the roentgen rays do not make the photograph directly on the film but they are made with rays emanating from the fluorescent screen after the roentgen rays have been transformed into visible photographic rays. The difficulty lies in the weakness of the image produced by the fluorescent screen, and for this reason an especially powerful optical system had to be constructed. The author had such an enormously powerful system made and gives a diagrammatic sketch of the whole apparatus. By means of it cinematographic roentgenograns can be taken without any greater exposure of the patient than in ordinary diagnostic examinations.—*Audrey G. Morgan.*

Bouwers, A. Über die Technik der Momentaufnahmen. (The technique of time exposures.) *Acta radiol.*, Apr. 15, 1931, *12*, 175–183.

The author discusses the most favorable conditions for time of exposure and size of focus. Apparently, independently of conditions of exposure, the greatest sharpness is obtained when the geometrical lack of sharpness due to the size of the focus is twice as great as the lack of sharpness caused by movement of the object. For the conditions of exposure that occur in practice the lack of sharpness is calculated as a function of the exposure time and shown by means of curves. The curves demonstrate that the above theory is correct but that practically quite good results can be obtained when the geometrical lack of sharpness and that due to movement are equal.

The improvement brought about by using a tube with a rotating anode is shown by the curves, and calculations given showing the best exposure time and best size of the focus when using such a tube. The use of an intensifying screen increase sharpness as long as the lack of sharpness of the screen is less than that due to other factors, but not otherwise. A high-tension generator designed by the author for tubes with a rotating anode is described which ensures the best conditions for taking pictures.—*Audrey G. Morgan.*

Krebs, Carl, and Busch, Fanny. The radiosensibility of human lymphosarcomas, determined by heterologous transplantation. *Acta radiol.*, Sept. 30, 1931, *12*, 395–400.

It has previously been demonstrated experimentally that the lethal dose for mouse sarcomas and carcinomas is about 5 or 6 erythema doses and the lethal dose for mouse lymphosarcomas is about 2 erythema doses. The authors describe experiments which they made for the purpose of determining the lethal dose for human lymphosarcomas. They grafted the human lymphosarcoma tissue into mice before irradiation and after irradiation with 1/2, 1 and 2 erythema doses. The non-irradiated tumor tissue "took" in about half the cases, while after irradiation with 2 erythema doses there was only one take in 90 cases. They conclude therefore that the lethal dose for human lymphosarcoma is about the same as that for mouse lymphosarcoma, namely, 2 erythema doses.—*Audrey G. Morgan.*

Hartmann, Josef Heinrich. Verstärkerfolien, ihre Beurteilung und Eigenschaften. (Intensifying screens, their testing and their properties.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, June, 1931, *43*, 758–776.

This is a technical article dealing with the characteristics of intensifying screens and the various tests of their properties. Generally the sharpness of the image depends on the following factors of intensifying screens: (1) the size of the grain particles of the fluorescent material; (2) the thickness of the screen layer and the quantity of the fluorescent material per unit surface; (3) the reflection of the fluorescent radiation at the under surface of the screen, and (4) the absorption of the fluorescent light by the thickness of the intensifying screen. An improvement in the sharpness of the image is obtained by the following changes of the above factors: (1) use of fluorescent material of very fine grain particles; (2) use of a very thin layer of the material with a small quantity per unit surface; (3) application of protective layers absorbing the fluorescent radiation of the under surface of the screen, and (4) use of material with utmost fluorescent emission, but with the least possible afterglow. This latter may be especially disturbing in serial roentgenography and flash exposures.—*T. Leucutia.*

Creuzberg, G., Dannmeyer, F., Hartleb, O., Lederer, E. L., v. Noël, L., Schubert, J., Seel, H. and Treplin, L. Studien am Blute Karzinomatöser. (Studies of the blood of carcinoma patients.) *Strahlentherapie*, 1931, *42*, 609–709.

Dannmeyer of the Hamburg-Eppendorf Hospital believed that something might be learned about cancer by correlating the studies of physicians, physicists, chemists and various specialists. This article is a result of such group study and it was found that the work of one group of specialists frequently confirmed the results of that of another.

Dannmeyer and Seel call attention to the fact, shown by Warburg, that the carcinoma cell catabolizes sugar to lactic acid to such an extent that this form of catabolism may be considered specific for the carcinoma cell. Lower fatty acids, such as pyroracemic and acetic, are also formed. But the higher fatty acids are also important in carcinoma metabolism. There is a tendency for the higher fatty acids to increase in the fat tissue in carcinoma and in old age.

v. Noël studying the chemical side of the problem worked out a formula for determining what he calls the cancer number, based on the alkali consumption of normal and carcinomatous blood. If the content of the blood in low-molecular fatty acids is increased then there is a larger consumption of decinormal sodium hydroxide solution. The details of the chemical method are described. The number for normal blood is 100 and in carcinoma it is 130 or over; the figure in other diseases was also found to be lower than 130. When the catabolism is carried through lactic acid to pyroracemic acid and acetic acid the figure is still higher so that it should be possible to determine to a certain extent the stage of progress of the cancer. In normal individuals also the high-molecular fatty acids not soluble in water predominate over the water-soluble, low-molecular ones while in cancer cases the reverse is true. In cancer cases, too, the cholesterin content calculated for 1 mg. total fatty acids is less than 0.2 while in normal cases it is more than that. The cholesterin content calculated for 1 mg. high-molecular, water-insoluble fatty acids is higher than the cholesterin content calculated for 1 mg. water-soluble, low-molecular fatty acids in cancer cases while the reverse is true in normal cases.

Dannmeyer, Hartleb and Schubert made a spectrometric study of the blood serum and give illustrations of the curves in normal and cancer cases. An analysis of the spectra showed that not only is free blood sugar transformed into lactic acid but that the combined sugar, which is not shown by blood examination, is involved in the lactic acid fermentation. This sugar was demonstrated in normal blood but could not be determined quantitatively. In carcinoma the combined sugar disappears. The "cancer virus" therefore must have a capacity for setting sugar free from its compounds. Further studies will have to be made of the metabolism of combined sugar.

Lederer studied the comparative protective action of the sera of normal subjects and carcinoma patients against suspensoids. There should be a difference if the blood serum of carcinoma patients shows a lower albumin content and a higher acid content than that of normal individuals. This reaction was tested using Berlin blue as a suspensoid and a cold saturated salt solution as an electrolyte. All non-cancer cases were negative and 75 per cent of the cancer cases were positive. The reason for the negative result in the other 25 per cent of cancer cases is not known. This is a preliminary report and the reaction is being studied further.

Creuzberg and Seel made animal experiments in which they tested the effect of blood and tissue extracts on the growth of mouse tumors. Extracts from the blood of carcinoma patients did not show any perceptible effect on tumor growth. Extracts of the blood of normal individuals sometimes inhibited growth to some extent but not enough so that definite conclusions could be drawn in regard to their use. Bivalent iron in the form of ferrosaccharate used in conjunction with ultraviolet irradiation distinctly inhibited growth.

Treplin discussed the clinical side of the question. He has found from clinical experience that when v. Noël's cancer number, the spectrometric cancer curve and the Lederer flocculation reaction all agree the diagnosis of cancer is certain. Possibly, too, the blood examinations will furnish a means of determining when a patient is free of cancer. Heretofore the roentgenologist has had to irradiate empirically after operation and there was no way of determining when the optimum amount of irradiation had been given. It may also become possible to demonstrate precancerous conditions. That is, it may be possible to demonstrate anomalies in metabolism which show a cancer predisposition before there are manifest signs of the disease. At least it has been shown that cancer is a disease of metabolism of which the tumor is the last manifestation. With such early diagnosis it might be possible to devise means of treating

the disease of metabolism before tumor develops.—*Audrey G. Morgan.*

Langendorff, H., and Langendorff, M. Strahlenbiologische Untersuchungen an den Keimzellen des Seeigels. (Radiobiological examination of germinating cells of the sea urchin.) *Strahlentherapie*, 1931, *40*, 97–110.

The sensitivity of the eggs and sperm of the sea urchin (*Psammechinus miliaris*) to roentgen rays of 180 kv., 3 mm. Al filter, and 5 ma., was studied. Doses of 50, 100, 200, 300 and 400 r were applied, and the percentage of larvae damaged was calculated for each dose. The damage was in proportion to the roentgen doses. In each experiment the damage curve obtained was similar to an exponential curve. The sperm was more radiosensitive than the egg. Irradiation of fertilized eggs showed that the damage depends upon the time interval between irradiation and fertilization. The various states of mitosis were examined by irradiating the cells at intervals of four minutes after fertilization. The irradiation damage was the greatest shortly after fertilization. It then decreases and reaches a minimum at the metaphase, and increases again at the beginning of the anaphase.—*Otto Glasser.*

Jalin, R. I. Über die Diffusionsosmose der Jodionen im Muskel unter der Einwirkung der Röntgenstrahlen. (On the diffusion osmosis of the iodine ions in muscle under the influence of roentgen rays). *Fortschr. a. d. Geb. d. Röntgenstrahlen*, April, 1931, *43*, 494–497.

The author carried out a number of experiments (31) in rabbits to determine the influence of roentgen rays on the rate of diffusion and absorption of the iodine ions in the muscle (the musculus tibialis anticus having been chosen for this purpose). The iodine was applied in the form of injections of a 2 per cent solution of potassium iodide directly into the muscle and the rate of diffusion and absorption was measured by the electric test according to the procedure of Stscherbak (the technique, because of its previous description by Bruck, is not mentioned in the present article). The irradiation was carried out with roentgen rays with various filters either locally, on the injected area, or generally, with the injected area protected by lead.

It was found that roentgen irradiation resulted in an acceleration of the diffusion and absorption of the iodine ions, this being especially pronounced with the use of the soft rays administered in the form of general irradiation. This again proves that the "indirect" effect of the roentgen rays, most probably through the intermediary of the vegetative nervous system, is of paramount importance.—*T. Leucutia.*

Levine, William T. Pigmentary reaction in Rana clamitans larvae following treatments with x-rays. *Proc. Soc. Exper. Biol. & Med.*, March, 1931, *28*, 594–596.

Certain conspicuous changes occur in the dorsal skin, especially the formation of whirls by the epidermal melanophores preceding their disintegration. The animals, after being narcotized in a 1:10,000 solution of water-soluble anesthesin, were placed on water-soaked cotton and exposed to unfiltered roentgen rays.

Two stages of the pigmentary reaction following roentgen treatment are described. In the first case 10 tadpoles, 43–45 mm. body length, and 8–10 mm. hind leg length, were given 8 treatments of 92 kv., 5 ma. at 10 inches from the cathode. The animals were exposed for 10 minutes every other day and killed after the last treatment. The previously round pigment dots became streaky and comma-shaped. Later they began to converge toward one or several centers which most often were located in the scapular and pelvic regions. Eventually there occurred a hyperplastic rise of the epidermis and perforation in the center, plugged with a blood clot. Examination of sections and whole mounts showed that the epidermal melanophores, normally irregularly arranged, had become oriented in one direction.

A second group of 10 tadpoles was exposed on two consecutive days for 45 minutes at 125 kv., 5 ma., at a distance of 10 inches. One or two days after the second treatment they presented not only a formation of whirls, but also a noticeable decrease in epidermal pigments.

It seems that the pigmentary dislocations are not specific to external stimuli but rather to internal disturbances due to various causes. —*B. Cohen.*

Saxe, Erwin. Die Änderung der biologischen Wirksamkeit von Membranen unter dem Einfluss von Röntgenstrahlen. (The change of

the biological activity of membranes under the influence of roentgen rays.) *Strahlentherapie*, 1931, *40*, 125–132.

The regulation of the balance in the nutritional household of the cell is mainly dependent on two factors: (1) the electro-osmotic difference of the potential between the various parts of the cell contents and the external surroundings of the cell, and (2) the change of the properties of the membrane.

The chemical change of the cell contents, of blood, of irradiated fluids, etc., through chemical and physical influences has already been investigated.

In this paper the second question will be examined, with special reference to the change of the permeability of membranes under the influence of roentgen rays.

If the changes in the cell tissue were comparable to those of an anorganic reversible system, the final osmotic balance between cell contents and surroundings of the cell would only depend upon the solutions on both sides of the membrane. According to Pfeffer's first law, the osmotic pressure is independent of the special characteristics of the semipermeable membrane. Inasmuch as the biological reactions of the cell mechanism are mainly irreversible chain reactions, the relatively quickly passed stages of synthesis and decomposition in the cellular metabolism cannot be considered final products. The final course of the reaction depends upon the manner and time in which each of the consecutive chemical phases are completed. The migration of matter and the metabolism in the cell tissue is changed through the specific variation of the individual proceedings at the diffusion. Thus for the vitally important problem of graded reaction in the normal and diseased organism of the cell the examination of specific differences in the passage of solutions through normal and treated membranes is of vital importance.

A specially constructed apparatus is used in the experiments.

Various tables show, by comparison, the results of diffusions through normal membranes and through membranes which were subjected to roentgen irradiation of different dosages. They show primarily that the rate of diffusion through an irradiated membrane is fast in the beginning and then gradually declines. But there is a difference in the rates of diffusion, after changes in the amount of radiation dosage have been made. In this case the curves, pointing out the mathematical equation of the rates of diffusion through the normal and the irradiated membranes, are in a characteristic relation to each other, thus proving that this effect is dependent upon the dosage.

This physical influence on the properties of the membranes opens a new view on the possibility of a characteristic part of the metabolism, heretofore not fully recognized in its importance and on the possible study of these biologically important factors *in statu nascendi*. There should be a possibility of changing the properties of membranes through physical and chemical influences, and of producing those effects which until now have not been fully explained by changes of the purely osmotic conditions.—*Morris Dreyfuss.*

Pohle, E. A., Ritchie, Gordon, and Wright, C. S. Studies of the effect of roentgen rays on the healing of wounds. *Radiology*, April, 1931, *16*, 445–460.

The authors exposed two groups of white rats to two qualities of roentgen rays, preceding or following incisions in the skin. It was found that irradiation with either quality of the rays, in a dose of 1000 r at one sitting, from one to thirty days before the incision did not affect the healing process perceptibly. Irradiation with a dose of 1000 r with rays of either quality, immediately, twenty-four hours and forty-eight hours, respectively, after the incision, retarded the healing process, particularly in the twenty-four-hour group, but did not interfere with the final formation of a smooth scar.—*J. D. Camp.*

Bostrom, G. The utilisation of electrocoagulated tumor-tissue in histological diagnosis. *Acta radiol.*, Apr. 15, 1931, *12*, 184–189.

The author studied the possibilities of making a correct microscopic diagnosis from the examination of tumor tissue that has been subjected to electrocoagulation. The chief practical advantage of the method is that a piece of coagulated tumor can be removed and examined without the risk of dissemination of the growth that is seen in preoperative biopsies. At Radiumhemmet electrocoagulation is now used in the treatment of carcinoma of the vulva, of malignant tumors of the mouth and of certain naevi and skin carcinomas. He finds

that as a rule a microscopic diagnosis can be made from the examination of electrocoagulated tumor. The coagulation caused by electrothermy does not differ greatly from that brought about by other methods of fixation. The method that most nearly coincides with electrocoagulation, that by boiling, has for a long time been used for the fixation of albuminous body fluids. The changes brought about by electro-coagulation were so severe as to render microscopic diagnosis impossible in only about 5 per cent of the cases examined. The degree of change is determined by a number of factors, such as the strength of the current, duration of application, water content of the tissue and distance from the electrode.—*Audrey G. Morgan.*

Leake, James P. Radium poisoning. *J. Am. M. Ass.*, March 26, 1932, *98*, 1077–1080.

Fatal cases of radium poisoning in luminous dial painting had occurred two years before 1924 when the hazard was first recognized. Pointing the brush with the lips has not been done since 1926. A study of dial painting factories in the United States since 1926 showed markedly improved conditions. No case of injury to any individual exposed only since that date has been found. Although a small amount of radioactive element was found in the bodies of workers it was not sufficient to produce bone changes, dental disease or other clinical manifestations. The investigation indicates the possibility of the industry being carried on in entire safety though further efforts to control dust inhalation are necessary to prevent accumulation and provide a factor of safety for varying susceptibilities.—*E. W. Hall.*

Fischer, Albert. Mesothoriumbestrahlung von Gewebszellen in vitro. (Mesothorium irradiation of tissue cells in vitro.) *Strahlentherapie*, 1931, *40*, 54–96.

Experiments in radium irradiation of tissue cells in vitro are described. They show that the irradiation causes an inhibition of growth after a certain time. The latent period is a real one and not simulated by the method of measurement used, for tissue cells from freshly transplanted cells that were not irradiated grew and also ones that were irradiated for five hours with an amount of mesothorium corresponding to 40 mg. radium.

The author tries to account for the latent period. It cannot be accounted for by saying that the cells that were undergoing mitosis were struck by the rays, for the inhibition of growth was much greater than could have been caused by the number of mitoses occurring during the irradiation. Cultures irradiated at a low temperature showed even greater inhibition than ones irradiated at body temperature. The experiments did not show any evidence that the latent period is caused by using up the reserves of certain substances vital to the life of the cells which they could not build up again during the irradiation. There was evidence indicating that the progressive inhibition of growth was due to the progressive production of injurious products of metabolism. Irradiated cells set substances free that inhibit growth. The effect of these cells on intact normal cells can be demonstrated.

The duration of the latent period can only be slightly affected. Its duration, with equal doses is not dependent on the rapidity of proliferation of the cells, as was formerly believed. It varies with the intensity of the irradiation. On injury of the irradiated cells the latent period is shortened and the inhibition of growth is greater than in uninjured cultures. Any demands made on regeneration, increase the effect of irradiation. The processes which lead to inhibition of growth take place, though more slowly, at subnormal temperatures. The resistance of the irradiated cells is decreased by either rapid or slow proliferation.

The experiments show that the absolute action of irradiation is the same in slow and active proliferation. The effect of the irradiation on resting cells remains latent and does not become manifest until the cells begin to proliferate. The point of action of the rays on the cells is probably the same no matter whether the cells are undergoing mitosis or not; they probably act on the material on which the catalyzers of proliferation act. The Bunsen-Roscoe law of photometric reactions does not hold good for the biological action of radium irradiation.—*Audrey G. Morgan.*

Mottram, J. C. Experiments on the susceptibility of tumors and tumor cells to radiation. *Acta radiol.*, Feb. 14, 1931, *12*, 1–7.

A fast-growing Jensen's rat sarcoma and a slow-growing rat sarcoma were irradiated for

purposes of comparison. In all cases, gamma radiation was applied to small pieces of tumors of approximately 1 cubic millimeter between thin sheets of mica. Two applicators were used, one above and one below. Tables are given showing the details of the results. Susceptibility to beta radiation had been tested in a previous series of experiments. There was very little difference in the susceptibility of the fast-growing and slow-growing tumors to either beta or gamma radiation. The embryonic skin of the rat also showed approximately the same susceptibility to gamma radiation. Apparently, therefore, the differences in the sensitiveness of fast-growing and slow-growing tumors to radiation found in vivo or when treated clinically are due to the effect of the radiation on the living tissue outside the tumor cells. From previous experiments it would seem, too, that the action of the rays on the blood vessels accounts in part for the differences in effect when irradiation is given clinically.—*Audrey G. Morgan.*

DE RAADT, O. L. E. Über die Ernahrung der Krebskranken nach Caspari (Caspari's theories in regard to food in cancer.) *Strahlentherapie*, 1932, *42*, 800–802.

De Raadt says there are contradictions in Caspari's theories in regard to food in cancer. Caspari advises using a diet poor in vitamin B, carbohydrate and potassium salts. He advises limiting vitamin B and particularly B2 because vitamin B in the food stimulates the growth of transplantation tumors in rats and mice. But he also says that feeding with raw meat alone limits the growth of the tumors and that meat is rich in vitamin B2. De Raadt explains this contradiction by claiming that the action of meat in inhibiting the growth of tumor is due to its being strongly acid and has nothing to do with its vitamin content. On this basis there is no reason for refusing to allow the patient to use liver. Caspari also says that the water in which vegetables is cooked should be thrown out as it contains most of the vitamin B. But de Raadt says that this also changes the vegetables from an alkaline to an acid food. Caspari forbids the use of carbohydrates and this too is a question of acid-base balance. Caspari says that potassium salts stimulate the growth of tumor and yet he uses potatoes which are richer in both potassium and vitamin B than polished rice. Caspari says that not much is known about acid-base balance in tumor but de Raadt says that it has been shown that in the beginning of cancer development there is alkalosis which later often changes into acidosis (Schneider and Achelis).

De Raadt says that in 1925 he advised treating cancer patients with an acid diet and that when Caspari's diet is considered carefully its value is found to lie in the fact that it is acid and that he (de Raadt) is therefore entitled to priority in the question.—*Audrey G. Morgan.*

CASPARI, W. Erwiderung auf die Ausführungen von Herren de Raadt über die Ernahrung der Krebskranken. (Reply to de Raadt's article on diet for cancer patients.) *Strahlentherapie*, 1932, *42*, 803–808.

In reply to de Raadt's criticism of his work on diet in cancer, Caspari admits that he should have said that meat is relatively rich in vitamin B2, which is only a part of the vitamin B complex in which meat is poor. He meant only that in meat the vitamin B2 constitutes a relatively large part of the vitamin B that is present. De Raadt says that without an alkaline diet there would be no cancer, but in inhabitants of the tropics who live mostly on fruit there is little cancer. De Raadt says that Caspari has not considered the question of acid-base balance in diet in cancer. Caspari refers to previous work showing that he has but he brought about inhibition of cancer growth with an acid diet poor in vitamin and carbohydrate, and Ottensooser obtained the same results with an alkaline diet rich in carbohydrate and free of vitamin. The only common factor in the diets was the lack of vitamin and the undernutrition so they conclude these were responsible for the results. With reference to liver in the diet he says that regardless of de Raadt's theoretical considerations his experimental work has confirmed the fact that it is harmful. He admits that he does not consider the potassium factor of very great importance; he did consider rice as the classical food for producing B-avitaminosis but rice is comparatively little used in Germany and bread and potatoes are staples of diet, so he allowed his patients to use potatoes for carbohydrate instead of rice. With reference to de Raadt's quotation of Schneider and Achelis he says that some authors have found acidosis in cancer and some alkalosis and the question is by no means settled.

The whole point of de Raadt's objection to his work seems to be that he claims priority. Caspari says that he himself claims no priority but was simply describing the results of his experimental work.—*Audrey G. Morgan.*

Edlbacher, S. Die Abartung des Chemismus der Krebszelle. (Abnormalities in the chemism of the cancer cell.) *Strahlentherapis*, 1931, *42*, 929–938.

The normal cell "breathes," that is, it breaks down sugar by oxidation. Warburg has found that the cancer cell catabolizes carbohydrate to lactic acid anaerobically by fermentation. This fermentation or glycolysis is characteristic of the tumor cell. Waldschmidt and Leitz have found that tumor cells also show increased proteolysis, though this is denied by other authors who say that there is no difference in the proteolytic activity of extracts of normal and tumor cells. The author has found increased catabolism of arginin and nucleinic acid by tumor cells. Normal muscle never shows a dephosphorization reaction but the muscles of animals with tumor and of cancer patients gives a positive reaction which is even more intense than the reaction of the tumor tissue itself. The organs and particularly the muscles of tumor animals are therefore in a condition of "chemical allergy," that is, the tumor has a distant action on the whole organism and changes the metabolism even of apparently normal cells in the direction of its specific abnormality.

The author believes that malignancy is a disease of metabolism and that the site of the tumor only represents a point of least resistance. None of the known facts is in contradiction with this theory and it is supported by the facts which he gives in regard to chemical allergy. Rous's chicken sarcoma has been transmitted by solutions which did not contain cancer cells. Probably the transmission was brought about by substances which act on the essential functions of the cell nucleus bringing about abnormal metabolism. It is not known whether the increased capacity for growth of the cell nucleus brings about the increased glycolysis which produces energy, or vice versa, but the author is inclined to believe that the primary abnormality is in the chemism of the process of cell division.—*Audrey G. Morgan.*

Dietrich, A. Wesen und Ursache des Krebses im Lichte der pathologischen Anatomie und der experimentellen Pathologie. (Nature and cause of cancer as shown by pathological anatomy and experimental pathology.) *Strahlentherapie*, 1931, *42*, 913–929.

The author reviews the history of the pathological anatomy of cancer and discusses the theories of Virchow, Cohnheim, Weigert, Albrecht, Ribbert, and others. He also reviews the later experimental work in producing cancer in animals. He concludes that there is some truth in the various theories but that none of them contains the whole truth. Tumors do develop from embryonic anlagen but the attempts to produce tumor by the implantation of embryonic cells have shown that there is an essential difference between embryonic cells and tumor cells. Embryonic cells have a capacity for differentiation and further development which the tumor cells have lost. But tumors may develop not only from embryonic tissue but from tissue changes in later life; they may be defective attempts at regeneration, as in the case of tumors which develop in scars and fistulas, in lupus or chronic diseases of internal organs, such as gallstones or chronic stomach ulcer. But either embryonic or regenerative exclusion of tissue from its normal connections is only one factor in tumor production. It creates the determining factor (anlage) but there must also be an exciting factor, which may be local, such as chronic irritation, or a general change in body metabolism, a tumor predisposition or constitution.

While the experimental work in the production of tar cancer and the metabolic studies of Warburg which have shown that cancer tissue obtains its energy by splitting sugar and forming lactic acid are of immense value, they have not replaced the methods of pathological anatomy as some have claimed. Morphology has laid the foundation on which other methods of research can build; the newer methods must utilize, not reject, what has been discovered by the old and every method has its limitations.—*Audrey G. Morgan.*

Bauer, K. H. Die Bedeutung der Vererbungsbiologie für das Geschwulstproblem. (Importance of the biology of inheritance in the cancer problem.) *Strahlentherapie*, 1931, *42*, 939–970.

The fact that tumors occur not only in human beings but also in animals and even plants shows that the problem of cancer is one of gen-

eral biology. From an exhaustive study of the problem of mutation the author comes to the conclusion that tumors are brought about by mutation. Tumor cells develop in an uninterrupted sequence of generation from normal body cells. They are differentiated from the original cells by characteristics which are transmitted by the primordial tumor cells to their descendants. Tumor development is a part of a normal life process. Mutation is one of the oldest and most fundamental processes in life. Changes and adaptations to conditions are brought about by gradual changes in the genes and chromosomes of the cells. Evolution would be impossible without these changes. But there may be regressive as well as progressive mutations; they do not fit into the general harmony of development and so bring about anomalies, malformations and diseases. Slight deviations in the wrong direction transmitted through many generations finally lead to catastrophic results.

Tumor formation in man differs from that in the lower forms of life only in its greater frequency. This is due partly to the change in biological selection in man. In plants and animals harmful factors are quickly eliminated by natural selection but in man they are preserved and transmitted. It is also partly due to the fact that man, protected by civilization, reaches a much greater age than other organisms which are saved from cancer by dying early.—*Audrey G. Morgan.*

TAYLOR, LAURISTON S., and SINGER, G. Further studies of the x-ray standard ionization chamber diaphragm system. *Radiology*, July, 1931, *17*, 104–112.

Further studies are presented on the effect of the diaphragm system upon the calibration measurements made with the large free air ionization chamber. Air absorption coefficients were obtained, and it was found necessary to use these values to correct the ionization chamber readings. Calibrations of a thimble chamber, made with and without a restricting diaphragm close to the roentgen tube, differ by several per cent. Dependent upon the position of the thimble chamber with respect to the tube target, the calibration may vary over a range of 10 per cent. When the radiation is not restricted by a diaphragm close to the tube, there may be a difference in the radiation quality received by the thimble and air chamber, as large as 10 per cent.—*J. D. Camp.*

GLASSER, OTTO, and BEASLEY, I. E. Eine Verbesserung an Grenzstrahlröhren. (An improvement in Grenz-ray tubes.) *Strahlentherapie*, 1931, *40*, 389.

The Lindemann window in a Müller Grenz-ray tube was replaced by a window consisting of a very thin indrawn bubble of glass. This window is situated inside a heavy glass sphere, and is therefore well protected against damage. It does not deteriorate with use. This window transmits softer rays than the Lindemann window, and permits the treatment of larger skin areas. Further experiments with still larger windows are in progress.—*Otto Glasser.*

WOLF, P. M., and RIEHL, N. Ueber einen neuen, sehr einfachen Apparat zur Erzeugung von Radiumemanation (Radon). (A new and very simple apparatus for the production of radium emanation—radon.) *Strahlentherapie*, 1931, *40*, 159–173.

After a discussion of the difficulties of obtaining radon preparations from the complicated Duane-Debierne or Rutherford vacuum emanation apparatus, the authors present their simple system of obtaining radon capillaries and other radium preparations. The containers to be filled with radon, in most cases gold capillaries, are filled with finely powdered, active charcoal. This charcoal has a highly absorptive power for the emanation. The capillaries are then connected tightly by means of a small special apparatus to the radium, which gives off the emanation. The best type of radium for this purpose is the dry radium preparation as discovered by O. Hahn. The technique of filling the tube with radon in the "radonator," as well as the various practical uses of the radon capillaries are discussed.—*Otto Glasser.*